SOCIOCULTURAL INFLUENCES ON THE DEVELOPMENT OF INFANTS' CULTURAL LEARNING SKILLS IN THE FIRST TWO YEARS OF LIFE.

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ABSTRACT

Within their first two years of life, infants develop the necessary abilities to learn from others in complex ways. The development of these so-called cultural learning skills is essential to a healthy development. Infants grow up in a multitude of environments across the world, however, it is unclear whether this influences the development of cultural learning skills. We focus our studies on two abilities that are crucial to interacting with others and understanding others' intentions, referential understanding and gestural communication, in particular the use of the index-finger pointing gesture. We use longitudinal data sampling to trace the onset and development of these abilities, as well as the influence of the socio-cultural environment.

The first study focuses on the development of referential point comprehension using a well-established paradigm by Behne at al. (2005), where hidden objects are indicated by index-finger pointing gestures. In addition we measured infants' social-interactional experiences using a point elicitation paradigm. The results showed that referential point comprehension develops gradually around infants' first birthday, contrary to social-cognitivists views (Csibra & Volein, 2008). We found both parental pointing as well as infants own use of the pointing gesture to be predictive of the development of referential point comprehension.

The second study addressed the ontogeny of index-finger pointing, comparing different potential predictors, both intraindividual cognitive and behavioral precursors as well as parental pointing using a point elicitation paradigm as well as observing infants' gesture use during free play and their ability to follow a simple pointing gesture. Both intraindividual predictors as well as socialization in the form of parental pointing were predictive of the onset of index-finger pointing. Further we included a second, cross-sectional study showing parents increased pointing for infants from 6 to 8 months of age.

The third study built on the results of the second study, in looking at potential predictors of index-finger pointing but also including infants' early language abilities and comparing parental gestural input across different settings (lab-based observations and naturalistic home-observations). Further, the third study included a more diverse sample of caregiver-infant dyads with and without a migration background. Similar to the second study, parental pointing (both at home and in the laboratory during the point elicitation paradigm) was predictive of the onset of index-finger pointing. Further predictors were parents' referential uptake of infants' early pointing gestures as well as parental gestures aimed at objects infants were focusing. In turn, the onset of index-finger pointing was predictive of language development, as were parental pointing gestures. Parents also adapted their input in accordance with their infants' development, increasing gesture use once infants started to use the index-finger pointing gesture.

Together, results support social-constructivist views (Liszkowski, 2018; Vygotskiĭ, 1978) of infant development, showing that interactional experiences shape infant development already during the first year of life. Further, this relationship is not unidirectional but both are intertwined from the very beginning with infants' emerging abilities informing caregiver interaction and caregiver interaction in turn shaping infants' development.

1. INTRODUCTION

What makes human cognition unique is our ability to learn from others, cooperate with them and enter into joint activities (Tomasello, 1999; Tomasello, Carpenter, Call, Behne, & Moll, 2005; Vygotskiĭ, 1978). The scope of these abilities is what differentiates us from other species (Tomasello, 2005). Participating in social practices as well as learning social and cultural artifacts (i.e. language) is of fundamental importance to the development of human cognition (Carpenter, Nagell, Tomasello, Butterworth, & Moore, 1998). Social interaction and participating in culture are among the most basic human needs, and essential to a healthy development. In essence, a child that grows up isolated from a human environment cannot learn.

Children grow up in a variety of cultural environments with differing impacts on their social and cognitive development. While the question of nature or nurture has been raised since the beginning of developmental research, the interplay between the socio-cultural environment and children's' social-cognitive development is still not entirely clear. Especially those abilities, which enable us to learn from others, our so-called cultural learning skills, and their interrelatedness with each other and the particular socio-cultural environment children grow up in, bear further study. How and when do these skills develop and is their development influenced by differences in the socio-cultural environment? The first two years of life, when most of the foundational skills for cultural learning are developed, are especially interesting in this regard. Are the early cultural learning skills like gestural communication and referential understanding influenced by early socialization? The aim of this thesis is, to further understand the development of specific cultural learning skills: gestural communication, focusing on the index-finger pointing gesture, and referential understanding of pointing gestures. Specifically, how infants' social interactional experiences influence the ontogeny and development of these abilities during the first two years of life, using longitudinal data collection.

1.1 Cultural Learning

Humans, compared to other species, show high cross-cultural variation of socially acquired behaviors (Haun, 2015), including written language, religions, values, rituals etc. This means that there needs to be a flexible system for learning these culture specific social skills and behaviors. In addition, this system would have to be adaptable to diverse ontogenetic contexts and cultural ecologies. The abilities that would enable us to learn and faithfully transmit these behaviors, should cultural learning be an evolutionary acquired skill, should be found across all populations but also have some sensitivity to cultural variation (Legare & Harris, 2016).

These abilities, our so-called cultural learning skills, are known to encompass abilities like understanding others' referents, intentions and goals, and being able to communicate about these with others, in complex ways (Carpenter et al., 1998; Lehmann, Feldman, & Kaeuffer, 2010; Tomasello et al., 2005; Tomasello & Carpenter, 2007). However, are these abilities truly evolutionary biological adaptations we are born with (Tomasello & Herrmann, 2010) or are they socially acquired (Heyes, 2012) or both (Legare & Harris, 2016)? In order to begin to answer this question it is necessary to identify the processes necessary for cultural learning through sampling different socio-cultural environments and their longitudinal influences on different cultural learning skills across different populations.

The basic question of nature vs. nurture has been raised since the beginning of developmental psychology research (J. M. Baldwin, 1884; Bruner, 1981; Vygotskiĭ, 1978; Werner & Kaplan, 1963). While no developmental scientist today would deny the influence of socialization on many important developmental milestones the question remains, when and how parental socialization influences infant development, especially during the first two years of life.

Some modern theorists still posit that all human abilities are learned through reinforcement learning (Deák, Krasno, Triesch, Lewis, & Sepeta, 2014; Jasso, Triesch, Teuscher, & Deák, 2006), though empirically, there is little evidence of their claim.

A more moderate account can be found in social-constructivist theories (Bruner, 1981; Carpendale & Lewis, 2004; Vygotskiĭ, 1978). Vygotskiĭ (1978), one of the early developmental scientist, would argue, that the development of our cognitive abilities is embedded in social and cultural structures from the very beginning Social-constructivist accounts would argue that most behaviors are acquired and socialized through joint engagement and social scaffolding even during the first year of life, without negating the possibility of some innate abilities (Carpendale & Lewis, 2006; Heyes, 2012; Liszkowski, 2018; Moore & Barresi, 2017; Vygotskiĭ, 1978; Werner & Kaplan, 1963).

In contrast, social-cognitive researchers emphasize that sufficient cognitive skills need to be in place in order for social-interactional input to have an influence and that cultural learning abilities are an evolutionary adaptation that emerges through maturation (Chomsky, 1988; Csibra, 2010; Fodor, 1981; Mundy & Newell, 2007; Spelke & Kinzler, 2007).

There is empirical evidence for all three approaches and I will present these in the later chapters. While an ultimate answer to this age-old question is difficult to attain, I will show evidence that human development it is a collaborative process from the very beginning, infant and parent reacting and adapting to each other, influenced by the larger socio-cultural context.

There are several ways to approach this overarching question, one way is to compare human development to that of other species, especially our closest evolutionary ancestors. Another is to look at human development across highly diverse populations to understand which abilities are universal and which are due to differences in socialization and environment.

1.1.1 Uniquely human?

Where do cultural learning skills come from? Are other species also capable of cultural transmission? There is evidence for at least some kind of cultural transmission among different species (Krützen et al., 2005; Lefebvre, 2013; van Schaik et al., 2003; Whiten et al., 1999). The earliest evidence, though rather anecdotal, comes from great tits in Britain learning to open milk bottles (Fisher & Hinde, 1949) and Japanese monkeys adopting the washing of sweet potatoes (Kawai, 1969). Newer studies were able to show cultural transmission in the wild across generations. For example, Luncz, Wittig, & Boesch (2015) studied wild groups of chimpanzees in Côte d'Ivoire, West Africa. They were able to show cultural transmission of different nut cracking tools within different social groups despite migration of females, with immigrating apes adapting their tool use to the strategy of their new group. Similarly, van de Waal, Borgeaud, & Whiten (2013), were able to experimentally manipulate foraging preferences in Vervet monkeys and show cultural transmission from mothers to infants as well as changes in behaviors upon migration to new groups. While cultural transmission in great apes and monkeys mostly concerns tool use and foraging preferences, studies of cetaceans show even further abilities. Transmission of whale songs have been shown in humpback whales across multiple populations and over an 11 year period (Garland et al., 2011). Similar transmissions of vocalizations and imitation have been shown other cetacean species like bottlenose dolphins and killer whales (Rendell & Whitehead, 2001).

It seems, cultural transmission, at least to some degree, is not unique to humans. However, the scope of these abilities both in adaptability and complexity is far greater in human beings and our use of symbols and traditions as well as the human scope of innovation and observational learning is unique among other species, indicating clear cognitive differences while also speaking to a common evolutionary ancestry (Lefebvre, 2013; Tomasello, 1999, 2005).

1.1.2 Cultural Variability

While there are many examples of cross-cultural differences concerning children's' cognitive skills and development (see Henrich, Heine, & Norenzayan, 2010b for an overview), evidence of socio-cultural influences on specific cultural learning skills are more scarce.

Recently Legare and colleagues published several studies on cross-cultural differences of imitation and over-imitation in infants, one of the driving forces of cultural transmission. Studying a diverse sample of infants in the US and different communities on Vanuatu, they observed a change in the fidelity of imitation when modeled actions were cued as conventional and a higher overall imitative fidelity of imitation of instrumental and conventional actions in Vanuatu children compared to US children, which they attribute to a greater socialization towards conformity in those Vanuatu communities (Legare, 2017; Legare & Nielsen, 2015; Legare, Wen, Herrmann, & Whitehouse, 2015). A second set of promising studies looked at cross-cultural differences and similarities in early gestural communication, especially index-finger pointing. The researchers were able to show a universal presence of the index-finger pointing gesture across several populations but also found differences in the age of onset of deictic gestures (Callaghan et al., 2011; Liszkowski, Brown, Callaghan, Takada, & Vos, 2012; Salomo & Liszkowski, 2013). Studying 8-15 months-old infants and their caregivers in three different cultures, Yucatec-Mayans in Mexico, Dutch families in the Netherlands and Shanghai Chinese families in China, Salomo & Liszkowski (2013) were able to show significant differences in the amount of joint engagement and deictic gesture use by caregivers, which were related to the frequency and onset of infants' gesture use. All of the studies cited above were cross-sectional, meaning longitudinal and or training studies are needed to confirm the data and understand more about the mechanisms involved. There is one longitudinal study, comparing infants in Nepal and West-Germany. The researchers analyzed naturalistic data collected over a period of 8 months, showing large differences in the interactional input the infants received. Interestingly, they did not find any differences in the time of onset of imitation, index-finger pointing or other deictic gestures (Lieven & Stoll, 2013). However, the sample for the 8 month old infants consisted of four infants (2 in Nepal, 2 in Germany), so while the results are interesting, larger sample sizes are needed to confirm them.

1.2 Defining the Socio-Cultural Environment

What do we actually mean when talking about the socio-cultural environment? There are several key aspects that make up the socio-cultural environment of infants and thus their cultural learning environments. These are classically described in two different ways. First, using macro level factors that inform each other like the amount of urbanization, the socio-economic status (SES) of the caregivers and overall cultural group (e.g. material wealth, occupation, access to education, high-quality neighborhoods, and social networks in addition to having decreased life stress (Bradley & Corwyn, 2002; Sohr-Preston et al., 2013), the values and socialization goals held by the cultural group (Kağıtçıbaşı, 2005; Kärtner et al., 2007), the family structure, etc. Second, using micro level factors, like the frequency and quality of caregiver interaction, the forms and frequency of gesture and language use, the forms and amount of teaching and scaffolding that are employed, etc. These micro level factors are what can actually enable us to learn more about the specific mechanism in development.

For example, parents' SES has been related to many different developmental outcomes (Conejero & Rueda, 2018; Harding, 2015; Noble, Korgaonkar, Grieve, & Brickman, 2013; Tacke, Bailey, & Clearfield, 2015) and especially the connection between SES and language outcomes has been shown many times, with children from higher SES backgrounds displaying more advanced language outcomes than children of low-SES backgrounds, which is usually attributed to the difference in quantity and quality of language input by caregivers (N. B. Brooks, Barner, Frank, & Goldin-Meadow, 2018; McGillion, Herbert, Pine, Vihman, & dePaolis, 2017) and this influence has been shown in infants as young as 18 months (Fernald, Marchman, & Weisleder, 2013). Rowe & Goldin-Meadow (2009a) used a longitudinal design and found out that differences in earlier gesture use, when infants were 14 months old, mediated the influence of SES on later language development. Already at 14 months, infants from higher SES families were socialized to use more gestures and communicate more meanings via gestures, which in turn had a large impact on their later language abilities. These results make a case for studying infants' early interactional experiences when considering later developmental outcomes.

Caregiver-infant interaction in the form of joint attention and caregiver scaffolding and teaching is foundational to human development and exist universally (Csibra & Gergely, 2009; Tomasello et al., 2005), however there are large qualitative and quantitative variations within and across cultures (Hewlett, Fouts, & Boyette, 2011; Keller, 2002; Keller et al., 2003; Keller et al., 2005).

Parents across different cultural communities hold vastly different ideas about whether parents should actively promote infant development with some cultures being mostly passive about infant development (Lancy, 2010). While infant directed speech is promoted in western cultures and linked to positive language development, some cultures do not use any infant directed speech (Lieven & Stoll, 2009). There are also different amounts of active teaching based on distinct ethnotheories about children's' capacity to learn through observation (Gutiérrez & Rogoff, 2003; Keller, 2007; Rogoff, 2009; Shneidman, Gaskins, & Woodward, 2016).

Researchers were able to show different mother-infant interaction when infants were only 3 months-old across 5 different cultural communities in West Africa, Gujarat India, Costa Rica, Greece and Germany. Mothers used different amounts of body contact, body stimulation, object stimulation and face to face contact (Keller, Lohaus et al., 2004), leading to diverging developmental outcomes on emotional self-regulation, mirror self-recognition (Keller & Otto, 2009; Keller, Yovsi et al., 2004) and delay of gratification (Lamm et al., 2017). These differences were traced back to parents' socialization goals concerning their infants' development based on cultural values related to relationality and independence (Citlak, Leyendecker, Schölmerich, Driessen, & Harwood, 2008; Giner Torréns & Kärtner, 2016; Kağıtçıbaşı, 2005; Kärtner et al., 2007). In a comparative study of Vanuatu and US infants, Little, Carver & Legare (2016) showed different amounts of verbal and gestural communication during triadic interaction, with Vanuatu caregivers using more nonverbal forms of communication like gesture and physical touch. Similarly, Salomo & Liszkowski (2013) presented results on cultural differences in the amount of deictic gestures and overall joint attention across 3 different cultural groups. Children across different cultures also tend to spend varying amounts of time with non-parental caregivers and peers (Keller, 2007).

Considering the high amount of cross-cultural variation in infants' interactional environments and the resulting differences in infants' development, further understanding the interrelation between caregiver input and infants' communicative development during the first two years of life is critical.

To summarize, there is some evidence of a common evolutionary ancestry of cultural learning as well as evidence for cross-cultural differences, making an influence of the socio-cultural environment on cultural learning skills likely. However, can we also find these differences when looking at the development of communication, particularly concerning index-finger pointing and referential understanding?

1.3 The Development of Communication

We know humans are social beings from the moment of their birth. Newborns already possess and keep developing abilities to refer to and interact with their environment. Prenatal infants show a preference for human speech in comparison to other auditory stimuli at birth (Vouloumanos & Werker, 2007) as well as the sound of their mothers voice in particular (DeCasper & Spence, 1986; Spence & Freeman, 1996). Newer studies were even able to show a preference for the mother's voice while infants were still in utero (Barbara S. Kisilevsky et al., 2003; B. S. Kisilevsky et al., 2009). Newborn infants are also already able to imitate their social partner (Meltzoff & Moore, 1977, 1989) and prefer stimuli that are similar to facial features (Goren, Sarty, & Wu, 1975), meaning they are born ready to interact with their environment and start learning from it.

Over the next years communication develops gradually, until around their first birthday infants are able to use different deictic gestures to actively interact with their caregivers and then in their second year of life they begin to refine their use of gestures and grow their gestural vocabulary (Guidetti & Nicoladis, 2008) and start to learn language (Kuhl, 2004).

Around their first birthday, infants also start to enter into so called "joint attention" with their caregivers, meaning both interaction partners are knowingly focusing on a third entity (Liszkowski, 2010; Liszkowski, Carpenter, Henning, Striano, & Tomasello, 2004; Liszkowski, Carpenter, Striano, & Tomasello, 2006; Tomasello et al., 2005). This joint attention or shared attention is the very basis of communicative learning for infants (Tomasello, 2007). These joint attention episodes offer infants the possibility of social learning (Striano & Reid, 2006; Striano, Reid, & Hoehl, 2006) and through their own use of deictic gestures they can actively seek out information from their caregivers (Lucca & Wilbourn, 2019; Wakefield, Hall, James, & Goldin-Meadow, 2018). For example, when infants hold out an object for them, a common reaction from caregivers is to name the object (Wu & Gros-Louis, 2013, 2015a, 2015b). Studies also show that infants expect a reaction from their caregivers when using deictic gestures and both frequency and tenacity of gestures is dependent on the communicative reaction of their interactional partner (Liszkowski et al., 2004; Liszkowski, Carpenter, & Tomasello, 2008). Liszkowski et al. (2004; 2007b) were able to show that 12 months old infants repeated their pointing gesture after the interaction partner had showed a positive emotional reaction but ignored the object they were referring to or attended to a different aspect of the object. While instances of attention towards a third object have been shown in younger infants, these were always initiated by the caregiver and could only be sustained through the caregiver (Adamson, Bakeman, & Deckner, 2004; Bakeman & Adamson, 1984).

Research has shown that experiencing frequent episodes of joint engagement is vital to infants' general development. The amount of joint attention in early childhood has been linked with the social (Mundy & Sigman, 2006), emotional (Claussen, Mundy, Mallik, & Willoughby, 2002) and cognitive development (Smith & Ulvund, 2003) of children, especially the development of language (Morales et al., 2000; Tomasello & Farrar, Michael, Jeffrey, 1986) and the development of a theory of mind (Charman et al., 2000). Studying the ontogeny and development of the two main abilities necessary for joint attention and thus cultural learning, the production of gestures and referential understanding of caregivers' gestures is essential to understand the mechanisms behind our uniquely human ability for complex cultural transmission.

1.3.1 The Development of Deictic Gestures.

Deictic gestures are the first active way of referential communication for human infants. They are non-symbolic gestures aimed to draw the attention of a communicative partner to an entity in the environment (Bates, Camaioni, & Volterra, 1975; Liszkowski, 2010; Volterra et al., 2003). Examples are index-finger pointing, i.e. using the extended index-finger aimed at a referent while the remaining fingers are curled up, or showing gestures, i.e. holding out an object into the others' field of view (Carpendale & Carpendale, 2010; Liszkowski, 2010). Contrary to iconic and conventional gestures, these do not have any specific meaning by themselves and can thus be used to direct attention to different referents, with the communication partner having to infer their specific meaning using an understanding of the others' intentions and cues based on the shared situation. Deictic gestures are the first manifestations of shared intentionality (Carpenter et al., 1998; Liszkowski, 2010, 2011).

Bates et al. (1975) were the first to describe the development of deictic gestures in human infants. They differentiated two distinct types of deictic gestures used by infants, so-called proto imperatives, meant to use the adult to attain entities from the environment and proto-declaratives, meant to direct others' attentions to an entity in the environment in order to communicate about the entity itself.

Developmentally, infants first start to use reaching gestures to attain objects out of their reach around 6 to 8 months (Bates et al., 1975). Ramenzoni & Liszkowski (2016) were able to prove that these gestures were actually communicative by showing that infants more often attempted to reach for objects out of their reach when adults were present. Around 8-10 months of age infants start using the open palm to point at objects as well as starting to show and/or give objects to their caregivers from around 9-10 months of age (Boundy, Cameron-Faulkner, & Theakston, 2016; Carpenter et al., 1998; Veena & Bellur, 2014).

Around 10-12 months of age infants start to use index-finger points (Behne, Liszkowski, Carpenter, & Tomasello, 2012; Bellagamba, Camaioni, & Colonnesi, 2006; Cameron-Faulkner, Theakston, Lieven, & Tomasello, 2015; Carpenter et al., 1998; Liszkowski et al., 2012; Matthews, Behne, Lieven, & Tomasello, 2012). Infants' ability to use pointing continues to improve even after the onset of language around 14-18 months of age (Carpenter et al., 1998). However, there is a large body of evidence that even around 12 months of age infants are already capable of using the index-finger pointing gesture in a similarly complex way as adults do (Tomasello, Carpenter, & Liszkowski, 2007), including referential intentions, social intentions and communicative intentions (e.g., (Krehm, Onishi, & Vouloumanos, 2014; Liszkowski, Albrecht, Carpenter, & Tomasello, 2008; Liszkowski, Carpenter, & Tomasello, 2007a). These early communicative behaviors, especially index-finger pointing indicate advanced social-cognitive and communicative abilities.

1.1.1.1.1 Index-finger pointing.

Research on the pointing gesture started in the mid-1960s (Werner & Kaplan, 1963). The very first studies on pointing were conducted using parent report questionnaires or interviews and some included home-observations of the infant (Bates et al., 1975; Werner & Kaplan, 1963). In recent years, specific experimental settings have been established to elicit infants' point production and comprehension (Behne et al., 2012; Camaioni, Perucchini, Bellagamba, & Colonnesi, 2004; Liszkowski et al., 2006; Liszkowski et al., 2012).

While other forms of pointing have been recorded, for example lip pointing (Enfield, 2001), which has been observed in several cultures of Papua New Guinea as well as chin-pointing (Wilkins, 2003), the index-finger pointing gesture has been shown to be a universal human gesture (Liszkowski et al., 2012). Liszkowski et al. (2012) were able to show index-finger pointing in different cultural settings in Papua New Guinea, the Rossel Islands, Indonesia, Bali, Japan, Kyoto, Peru, Mexico and Canada. What do we mean when we talk about index-finger pointing? Simple index-finger extension, which has been shown in infants as young as 3 months old (Hannan & Fogel, 1987), is not counted as true pointing behavior, since it is not an attempt to direct attention and is usually not directed at a specific object (see figure 1.1).

Figure 1-1 Index-finger extension by a 6-months old infant during a face-to-face situation.

Another form of pointing, usually occurring before infants start using the index-finger pointing gesture is the whole-hand point (see figure 1.2).

Figure 1-2 Still frame of a mother and her 13 month old infant during the joint activity of looking at objects in the laboratory.

Note. Left panel: infant index-finger point, right panel: infant whole-hand point

While whole-hand pointing has been considered a reaching gesture by some researchers (Leavens & Hopkins, 1999; O'Neill, 1996), newer studies (Cochet & Vauclair, 2010; Grünloh & Liszkowski, 2015; Liszkowski & Tomasello, 2011) show infants using index-finger pointing and whole-hand pointing during the same point-elicitation paradigm in a way that is clearly distinguishable from reaching gestures. One of the main indicators for both whole-hand pointing as well as index-finger pointing is body posture (usually the upper body is rather relaxed compared to infants leaning forwards when trying to reach for items) as well as the extension of the arm, which is used to distinguish the gesture from a simple index-finger extension.

What then makes index-finger pointing so unique? Compared to index-finger pointing, whole-hand pointing is not related to other cognitive skills or language (Liszkowski & Tomasello, 2011; Lüke, Grimminger, Rohlfing, Liszkowski, & Ritterfeld, 2016; Lüke, Ritterfeld, Grimminger, Liszkowski, & Rohlfing, 2017) and is less coordinated with vocalizations than index-finger pointing (Grünloh & Liszkowski, 2015).

The development of index-finger pointing has been shown to be important to language development (Butterworth & Morissette, 1996; Capone & McGregor, 2004; Cochet & Byrne, 2016; Colonnesi, Stams, Koster, & Noom, 2010; Iverson, Capirci, & Caselli, 1994; Iverson & Goldin-Meadow, 2005; Mumford & Kita, 2016; Rowe & Goldin-Meadow, 2009b; Sauer, Levine, & Goldin-Meadow, 2010) and cognitive development like later theory mind and referential understanding (Liszkowski & Tomasello, 2011; Sodian & Kristen-Antonow, 2015), it's abnormal development is an early symptom of autism spectrum disorders (Baron-Cohen, 1989a, 1989b; Behl Wulff, 1985; Goodhart & Baron-Cohen, 1993; LeBarton & Iverson, 2016; Osterling & Dawson, 1994).

Despite its' importance for infant development, little is known about the ontogeny of index-finger pointing. There is some evidence for some forms of pointing in other primates. The existence of pointing gestures between apes in the wild is unclear. Some researchers claim that they do, even if this behavior has only been observed on rare occasions (see Krause, Udell, Leavens, & Skopos, 2018 for an overview), while several authors (Gontier, 2013; Grosse, Call, Carpenter, & Tomasello, 2014) argue that pointing behavior consistent with communicative intent has never been observed in apes in their natural habitat. However, even if apes were to use pointing gestures in some cases, these would still not be as complex as the human use of the gesture. Some apes in captivity have been shown, to use pointing gestures when interacting with human experimenters though training was needed (Call & Tomasello, 1994; Leavens et al., 2015; Leavens, Ely, Hopkins, & Bard, 2012). Further, the testing is usually conducted using cage mesh that bars the apes from directly touching the items (Leavens et al., 2012). Compared to human infants, apes' ability to understand pointing gestures is limited. (Hare & Tomasello, 2004; Herrmann & Tomasello, 2006; Liszkowski, Schäfer, Carpenter, & Tomasello, 2009; Tomasello, Call, & Gluckman, 1997). Human infants use the pointing gesture from a distance to share something about the object with their communicative partner even if they could easily reach the item (van der Goot, Marloes H., Tomasello, & Liszkowski, 2014). And while apes' performance actually increases in competitive contexts (Herrmann & Tomasello, 2006) human infants do not only point to attain an item but also to share information and even helpfully provide information to others (Liszkowski, 2006; Liszkowski et al., 2007a, 2007b; Tomasello, Carpenter et al., 2007) and request information (Southgate, van Maanen, & Csibra, 2007).

1.1.1.1.2 Theories on the ontogeny of pointing.

There are various accounts on the ontogeny of pointing. Broadly, they can be separated into two categories, social shaping accounts and social cognition accounts. According to social shaping accounts, preceding infant behaviors (mainly reaching and non-communicative pointing) are shaped through caregivers' reactions into index-finger pointing (Bates et al., 1975; Carpendale & Carpendale, 2010; Vygotskiĭ, 1962). According to social cognition accounts, infants start to use the index-finger pointing gesture once they understand it, potentially through imitating their caregivers' pointing gestures (Butterworth, 2003; Tomasello, 1999).

The first account on the ontogeny of pointing comes from Vygotskiĭ (1962) who claimed that infants first start to reach for objects and through parents giving them the requested objects the behavior is shaped into index-finger pointing. Infants know when things are out of their reach at 6 months (Rochat, Goubet, & Senders, 1999) and infants have been shown to reach for objects selectively when someone is in proximity to give them the item (Ramenzoni & Liszkowski, 2016). However, one main problem with this account is on the side of caregiver shaping. The usual reaction from parents is not to point at the object but to give it to the infant. We also know infants to not simply point imperatively, they also point to comment on the object (Liszkowski et al., 2004; Liszkowski et al., 2007a) or to helpfully inform another person (Liszkowski et al., 2006; Liszkowski, Carpenter et al., 2008). Thus this account can at best explain imperative pointing but not informative pointing.

A recent paper by O'Madagain, Kachel and Strickland (2019) added compelling evidence to the theory of pointing from touching, showing infants both produce and interpret pointing gestures with their arms oriented in a way as if they were intending to touch the object as opposed to the arm forming an "arrow" to guide the other person's attention towards the object. According to them, parents start to orient their attention towards these objects, which infants recognize and then use "as if" touching gestures from further and further away to guide their parents' attention. This would potentially be able to explain both imperative and informative pointing, however, the authors were not able to offer an explanation as to how exactly the resulting socialization processes take place and whether infants this young would be able understand their parents mental states in a way that would enable to manipulate them in this manner.

Another account that has been raised for a long time is that of pointing first emerging without communicative intent and then through parents reacting as if that point was addressed to them paying attention to infants, thus rewarding them and infants in turn learning that attention can be elicited through pointing actions (Bates et al., 1975; Moore & D'Entremont, 2001). This is mainly based on the observations that early points observed from infants did not include vocalizations or gaze alternations, which they have been shown to be capable of at 11 months (Esteve-Gibert & Prieto, 2013), yet this behavior was observed just a few weeks later and absence of gaze alternation does not necessarily signal a lack of communicative intent (Liszkowski, Albrecht et al., 2008). Moreover, pointing is not reinforced by simply paying attention to the infant (Liszkowski et al., 2004). Carpendale and Carpendale (2010) used diary observation of infants and reported that infants touched objects with the extended index-finger before they started pointing. However, these index-finger extensions do not have anything to do with pointing, index-finger extensions happen during nursing, sleeping and object exploration as well as other situations (Carpendale & Carpendale, 2010; Hannan & Fogel, 1987) and the diary study included no information about caregiver shaping. Also, infants tend to start pointing using the whole-hand before using the extended index-finger, a fact that could not be explained through object exploration (Kita, 2003; Leavens & Hopkins, 1999; Lock, Young, Service, & Chandler, 1990).

On the side of cognitive precursors one relevant account is pointing from imitation (Tomasello, 1999). The idea here being that infants need to understand the intention of the pointer and be motivated to reproduce the goal of the pointer. However, referential understanding has been shown to emerge at about 12 months, later than the average onset of pointing (Liszkowski, 2018; Pätzold & Liszkowski, 2019). It might be that pointing starts of as simple mimicry of their caregivers actions due to affiliative motivations. Mimicry does not explain the complex way pointing is used when it develops and infants use whole-hand points before index-finger points and do not always use vocalizations and gaze alternations like their caregivers do (Liszkowski & Tomasello, 2011). Another cognitive account concerns pointing emerging from earlier gaze following (Butterworth, 2003). Pointing, at its core is meant to direct others' attentions, regardless of the motive. Infants are able to follow another person's attention and gaze before pointing emerges (R. Brooks & Meltzoff, 2005; Deák, 2015). Potentially infants start to follow their caregivers gaze while they are pointing and start to understand the connection between the point and the object. This account is not able to explain the multiple ways infants point from the moment they learn to use the gesture (see discussion above).

While none of the accounts on their own are exactly able to explain all forms of pointing, it's ontogeny is most likely based on a combination of different factors with caregiver socialization and infants' cognitive development being longitudinally interrelated and both influencing the other. We know from infants who are already able to use the pointing gesture that caregivers' reactions to infants' earlier points increased their pointing frequency during later months only when they represented a referential uptake of infants' pointing gestures (Ger, Altınok, Liszkowski, & Küntay, 2018).

1.3.2 Referential Understanding of Pointing Gestures

One of the foundational features of language and of communication in general is its referentiality – we need to understand that words and gestures are meant to refer to things. Before infants start to use language, they rely mostly on gestures to interact with their environment, and understanding others' gestures is crucial to their ability to learn from their environment. Do infants already understand the referential intent behind another persons' pointing gesture when they themselves start to point?

Using a longitudinal design, Carpenter et al. (1998) claimed, that infants represent their social partner's knowledge in joint attention tasks when they are about 12 months old. Liszkowski, Carpenter & Tomasello (2007a) were able to show that infants selectively repaired adult misinterpretations about the referent of their declarative points at 12 months old and also pointed to refer to absent objects that had been part of an earlier interaction. It seems plausible that in adult communication, pointing is based on understanding that others have the fundamental aim of cooperating with us in communication, therefore understanding them as mental agents, and also based on our ability to build up a representation of the common conversational ground. (Tomasello, Carpenter et al., 2007). So, how can these abilities and their acquisition in early infancy be approached? Behne at al. (2005) first introduced the so-called "point comprehension paradigm as an early test for the understanding of communicative intention.

In this test, an adult presents an exciting toy to an infant, which is then hidden under one of two cloths. Then, the adult indicates the place of the hidden toy by pointing to the hiding place. What will the infant do? The argument is that by searching in the right place and thereby understanding a point in this paradigm, the infant does not only need to direct her attention towards the referent of the gesture, but also understand the adult's intention to inform her that the hidden toy is under the cloth. This is no trivial matter, since it means to understand that others act out of a communicative intention and to make contact with some common ground. If we accept that argumentation, it seems plausible that if we observe an infant finding a toy at behavioral level (i.e. above chance), we may infer that she has acquired certain communicative abilities at the cognitive level.

Like every communicative act, pointing can be subdivided into abilities like perceiving the presence of a piece of information (point following), receiving a piece of information (point comprehension), or sending it (point production). Concerning the cognitive complexity of point comprehension, it is important to distinguish whether the infant wants the receiver to perform some kind of action, e.g. handing her an object which is out of reach, or intends to guide the receiver's attention towards an external object.

Behne et al. (2005) first presented evidence of children understanding referential point comprehension testing infants at 14, 18, and 24 months of age. An adult indicated the location of a hidden toy using a communicative cue, either by ostensively gazing or by pointing to the target container. Infants performed significantly above chance in finding the toy in all age groups and all cues. In a second control study, the authors manipulated the adult's communicative intention. By having the adult gaze absent-mindedly or pointing distractedly (i.e. by pretending to inspect her hand or wrist watch). Infants' search performance was at chance level, indicating that simple attentional cueing cannot account for the search performance, but that infants need to understand the *communicative* intent behind the cue. In a follow-up study using a similar set-up, Behne et al. (2012) were able to extend these findings to children aged 12 months, showing that around their first birthday, infants understand referential pointing gestures.

How do these findings relate to other aspects of pointing? There is no agreement in research whether infants comprehend or produce pointing first (Carpendale & Carpendale, 2010). Concerning the cognitive complexity, Camaioni et al. (2004) suggest that declarative, but not imperative pointing is connected to understanding of others' intentions. Having good reason to assume that there is a prelinguistic capacity in understanding others' intentionality from infants' first year, we do not know yet how it evolves.

It is well established that infants begin to follow the other's gaze direction within their visual field by 3 to 6 months (D'Entremont, Hains, & Muir, 1997; Gredebäck, Fikke, & Melinder, 2010; Striano & Stahl, 2005). Recently, Bertenthal, Boyer, and Harding (2014) showed that infants as young as 4 and 6 months shifted their attention in the direction of a pointing gesture, but not in the direction of an arrow. According to them, this early ability might already be the start of infants' developing understanding of triadic interaction. However, it is not easy to determine to what extent gaze following or even point following already forms a successful referential act in itself, as the infant does not necessarily need to understand that a person intends to direct her attention to something relevant to the established common ground (Behne et al., 2005). For example, Woodward (2003) examined the attention of 7- and 9-month-old infants when they observed an adult changing her gaze from one object to another. The author found the infant gaze-following to the first object, but not to the second one and concluded that they did not yet understand gaze as an action relating a person to an object. Hence, it has long been assumed that the understanding of the referential nature of gaze or points only occur relatively late in the latter half of an infant's first year.

Nonetheless, a few recent studies were able to evidence referential understanding more directly and earlier than previously assumed. With regard to the referential nature of gaze, Csibra and Volein (2008) conducted a violation of expectation study where 8- and 12month-old infants observed a person looking ostensively behind one of two occluders. When the occluders were moved away, a toy became visible at either side, consistent or inconsistent to the person's gaze. Even the 8-month-olds reacted with significantly longer looking in the inconsistent condition. The authors reason that by this age, infants expect to find a referent object when they follow others' gaze. In a pupil dilation paradigm, Pätzold and Liszkowski (2019) were able to show referential object expectation of an occluded object after a pointing cue in 12-month olds but not in 9-month olds.

Regarding referential understanding of pointing, Krehm, Onishi, and Vouloumanos (2014) presented a third-party scenario in which 9-month-old infants observed a person pointing for a recipient to one of two novel objects. The authors showed that these 9month-olds already responded with longer looking times when the recipient had perceptual access to the informative gesture and then selected the non-target. However, when the pointer used her fist instead of her index-finger or when the recipient did not have perceptual access to the informative point, longer looking times were no longer present. The authors conclude that by the age of 9 months, infants have some understanding that pointing can update the recipient's information state.

From a methodologically different perspective, Gredebäck, Melinder, and Daum (2010) presented an EEG-study comparing 8-month-old infants' processing of congruent and incongruent pointing gestures to the processing of adults. They found that the infants already processed congruent and incongruent gestures differently, with similar activation patterns as found in adults. Further, the neural correlates suggested that similar areas were activated as in processing gaze.

In summary, there is plausible evidence that by one year, infants have made progress in understanding others' intention. Prerequisites of understanding communicative intention, namely gaze following and more elaborate forms of joint visual attention, have been shown to increase in the second half of the first year. Moreover, there is recent evidence from looking-time studies suggesting that infants may understand others' communicative intention earlier than one year. However, a number of questions about the origin and developmental course of this ability is yet unsolved: When and how do infants start to understand communicative intentions? How does this ability develop over time?

What are the underlying mechanisms fostering this development? Does the social interactional experience, specifically infants' own use of the index-finger pointing gesture or their experience with their caregivers' pointing gesture influence the onset and development of these abilities? Some cross-sectional results point to a connection between the production and comprehension of pointing gestures, finding that at 12 months infants' correct search for a referred-to, hidden object correlates with their own ability to point to hidden objects (Behne et al., 2012; Liszkowski & Tomasello, 2011). It could be that social-interactional experience is actually necessary for the development of reference understanding, or a high amount of social interaction might speed up the development of this ability. Tomasello et al. (2005) would argue that infants' understanding of others perspectives emerges through social interaction. In their study, 14 months old infants had to be engaged in joint action and even at 18 months infants had to see a person actively manipulate an object to represent the perspective of the interaction partner. A person only observing the situation as a bystander was not sufficient (Moll & Tomasello, 2007). However, there is further need of longitudinal data to back up these results and add information about potential developmental directionality.

1.3.3 Language Development

Both gestural communication as well as referential understanding are developmental precursors of the onset of language production. However, the roots of language acquisition lie in early infancy (Tomasello, 2011). Infants start out life producing sounds like cooing and around 3 months they start uttering vocal-like sounds that turn into sound sequences and babbling, around 6 months the sounds of their respective native tongue become more and more dominant (Kuhl, 2004). The typical sounds infants utter during the second half of life, the so-called canonical babbling already contain the prosodic patterns of their native tongue (Höhle, 2005). Infants are now able to segment typical patterns of emphasis and language specific sound combinations and start using deictic gestures in combination with specific vocalizations (Chang, Barbaro, & Deák, 2016; Gros-Louis, West, & King, 2014; Grünloh & Liszkowski, 2015; Vilain, Schwartz, Abry, & Vauclair, 2011) marking the start of cooperative communication with their interaction partners. Around the same time they start producing their first words (Kuhl, 2004) and only a short time later, around 14 months, infants start to extract words from speech, recognize familiar words (Werker & Tees, 1999) and learn to associate objects with words (Werker, Cohen, Lloyd, Casasola, & Stager, 1998). Forgács, Parise, Csibra, Gergely, & Gervain (2018) showed that infants reacted to their communication partner noticing and incongruence between a label and an object. Infants also had similar neuronal patterns when watching another person "learn words" as they had when they themselves were processing language, indicating that infants already process language in a highly social way. Around 18 months most infants start using two-word combinations (Tomasello, 2011) and there is a steep increase in word leaning (Bates, Dale, & Thal, 1995). By five or six years of age, most of the grammatical and phonetic patterns of their native language are available to infants (Kany & Schöler, 2014).

As already mentioned in earlier chapters, infants' gestural communication, referential understanding and language abilities are developmentally intertwined in different ways. At the same time, caregiver communicative input also plays an important role in socializing communication especially language. Without their caregivers' input infants would not be able to develop a conventional language.

One obvious indication that the socio-cultural environment and infants' language abilities are interrelated is the well-established association between SES and language abilities, with many studies showing children from higher SES backgrounds display more advanced language than their lower SES peers at a preschool age (McGillion et al., 2017; Rowe & Goldin-Meadow, 2009a) and these differences are already apparent at 18 months, when infants only start using two-word sentences (Fernald et al., 2013) and are found across many different cultures, even in a country of overall low national income like Madagascar (Fernald, Weber, Galasso, & Ratsifandrihamana, 2011). One influencing factor might be the quantity and quality of caregiver lexical input, with lower SES caregivers potentially speaking less with their infants and using a less varied vocabulary (Hurtado, Marchman, & Fernald, 2008). The quantity, quality and diversity of caregiver linguistic input is an important predictor of later language development (Bornstein, Haynes, & Painter, 1998; Rowe, 2012; Weisleder & Fernald, 2013). However, other factors also influence infants' communicative development.

One of the main tasks of language acquisition is extracting words from speech (Werker & Tees, 1999). In order to give a meaning to these units of sound understanding of the context and referential understanding are vital. One main aid, besides the audible characteristics of speech comes from gestures, which are able to enhance or demarcate the symbolic meaning of specific words (Goldin-Meadow & Alibali, 2013; Igualada, 2014). The learning contexts necessary for this task are usually supplied by caregivers during the first two years of life, though as mentioned above there is considerable cross-cultural variance in the type and amount of caregivers infants have (Keller et al., 2005).

When looking at cross-cultural research on language development there is a large variety of cultural values, expectations of and goals for children's' development which influence the way caregivers socialize their infants' language development (Keller, 2006; Lohaus et al., 2011). Socialization influences on language development have been studied for decades, both in cross-cultural research (Bornstein, Tal et al., 1992; Tamis-LeMonda, Bornstein, Cyphers, Toda, & Ogino, 1992) and longitudinally (Bornstein, Vibbert, Tal, & O'Donnell, 1992) with evidence of both similarities in caregiver speech to their infants as well as different cultural preferences, showing evidence of socialization's influence on the developmental timetable of children's' language acquisition.

Caregivers use a multitude of gestures when interacting with their infants, most of these gestures are accompanying speech acts (Acredolo & Goodwyn, 1988; Iverson, Capirci, Volterra, & Goldin-Meadow, 2008). Co-speech gestures addressed to infants are strong predictors for later vocabulary development (Iverson et al., 2008; Pan, Rowe, Singer, & Snow, 2005). This might be, because these gestures help guide infants' attention (Bates et al., 1975; Wass et al., 2018), and provide context for adults' speech acts helping infants map words to actions and objects

(Tomasello & Todd, 1983). However, there is a second potential hypothesis, the amount of gestures directed at infants might actually influence infants' own gestural development, which in turn might be the more important predictor of later vocabulary size (Rowe, Ozçalişkan, & Goldin-Meadow, 2008) Indeed, the connection between infant gesture and language development and especially infant index-finger pointing and language development is well established and has been supported by a recent meta-analysis (Colonnesi et al., 2010) which also showed that this relation is true across different experimental and cultural settings (USA, Italy, England, Spain & Japan). Both the frequency of infants' pointing gestures (R. Brooks & Meltzoff, 2008) as well as the age of onset (Butterworth & Morissette, 1996) and the ability to use index-finger pointing over whole-hand pointing are predictive of later vocabulary (Lüke et al., 2016; Lüke et al., 2017).

What then makes pointing so powerful in relation to language acquisition? One explanation might be that infants' gestures and pointing in particular elicit the necessary words and sentences from their caregivers to advance in their linguistic development. It has been observed, that when infants point, caregivers will typically comment on the referent (Kishimoto, Shizawa, Yasuda, Hinobayashi, & Minami, 2007; Marcos, 1991; Wu & Gros-Louis, 2015b). Moreover, infants can use pointing gestures to reliably and specifically elicit information from their caregivers. Infants expect a referential response to their pointing gestures and will persist in pointing when they do not receive an adequate response (Liszkowski et al., 2004; Lucca & Wilbourn, 2019).

Once they are able to use their first words, they can also combine pointing as a referent and single words to form sentences, which in turn are usually replied to and repeated as full sentences by their caregivers, "translating" their infants speech acts (Goldin-Meadow, Goodrich, Sauer, & Iverson, 2007). A second and potentially additive effect is the idea that gesturing and thus using a multimodal approach might help infants learn new words. Igualdada, Bosch & Prieto (2015) observed infants at 12 months and documented co-speech gestures as well as singular pointing gestures and speech acts. Only multimodal pointing-speech acts predicted language abilities at 18 months. Research in school-aged children has provided evidence for this link. Children were better at problem solving when they were encouraged to produce gestures conveying a correct problem-solving strategy (Cook & Goldin-Meadow, 2006; Goldin-Meadow, Cook, & Mitchell, 2009).

Besides infants' gesture use and caregiver input, caregivers also respond to their infants' communicative attempts using gaze, gesture, touch and affect in addition to verbal responses informing infants' understanding and eliciting further communication (Wu & Gros-Louis, 2013; Yu & Smith, 2016). These behaviors are often characterized as *caregiver responsiveness.* Caregiver responsiveness to their infants' communicative attempts is correlated with infants' early phonological and vocalization development (Goldstein & Schwade, 2008) and later vocabulary size (Baydar et al., 2014; Nozadi et al., 2013; Tamis-LeMonda, Kuchirko, & Song, 2014). While the proportion of caregiver responses to infants' communicative acts has been shown to be developmentally stable during infants' first two years of life caregivers adjust the content of their responses to the ability level of their infants (Bornstein, Tamis-LeMonda, Hahn, & Haynes, 2008). Temporal contingency of caregiver responses is correlated with an increase of infant vocal complexity and an increase in infants' use of vocalizations to attain caregiver attention (Gros-Louis et al., 2014, 2016; Wu & Gros-Louis, 2014). Caregiver contingent language increases the odds that naming events occur (Suanda, Smith, & Yu, 2016). Caregivers responding to their infants' attentional frame, by also attending to the object the infant is focusing on, either by visually attending it, using gesture or verbal responses, leads to infant sustained attention (i.e. attention lasting longer than 3s) (Yu & Smith, 2016) which in turn is a strong predictor of later vocabulary size (Yu, Suanda, & Smith, 2019). Most likely, naming events that occur during sustained attention events make the name-object relation more salient for the infant.

To summarize, language is a gradually developing ability with roots in early infancy. Both infants' early gesture production, especially index-finger pointing, as well as caregiver gestural input and caregiver responsiveness have been shown to be predictive of infant language outcomes. Earlier chapters also demonstrated that these factors are themselves interrelated and are influenced by the socio-cultural environment of infants as well as their caregivers' cultural values and socialization goals. However, research resolving the complex developmental interrelations of these different abilities and influencing factors is scarce.

2. METHODOLOGICAL BACKGROUND

There is a broad spectrum of methodological approaches to studying the development of infant communication. Classically, cross-cultural research has focused on more anthropologically-informed studies, focusing on small sample sizes and more casual observations, making the isolation of developmental mechanisms and cognitive factors difficult. On the other hand, (neuro-) cognitive studies usually focus on highly experimental designs studying specific aspects of development and are usually cross-sectional in design. Many studies lack a longitudinal design, especially those focusing on the interrelations between cognitive and social development (Brune & Woodward, 2007; Carpenter et al., 1998) and even more rare are studies on non-WEIRD (Western, Educated, Industrialized, Rich and Democratic) samples (Henrich et al., 2010b; Nielsen, Haun, Kärtner, & Legare, 2017a). An approach often taken by cross-cultural research is to study populations that are as different as possible like comparing WEIRD samples to small hunter-gatherer communities. However, while comparing hunter-gatherer societies to western industrialized samples is likely to lead to cross-cultural differences, and is an important step for universality claims, generalizability of the results as well as an understanding of the developmental mechanisms involved can be low. Sampling different cultural groups from within one society allows controlling and comparing factors like SES, kindergarten attendance etc. while still including different variations of socio-cultural environments.

A second issue to consider is the question of how to measure parent-infant interaction as well as infants' communicative development. The most ecological way to measure infants' development is through parent questionnaires – however, those are liable to social desirability effects and different response styles (Harzing, 2016). The most ecologically valid way to measure both interaction and development would be to observe families at home over long periods of time with high density sampling, however, this is incredibly expensive and when trying to measure infant competence and cognitive mechanisms, this is liable to distractor variables.

Sampling interaction in the laboratory using free play settings with a set of toys provided and minimal instructions to the participants is the most popular way to sample interactions (Bakeman & Adamson, 1984). However, when directly comparing parental input at home and in the lab, higher amounts of attention, talking and responding were reported in the laboratory than at home while infant behavior seemed to be unaffected (Belsky, 1980; Kniskern, Robinson, & Mitchell, 1983), parents in the laboratory are more likely to exhibit behavior they deem to be highly socially desirable (Lamm et al., 2014). Laboratory observations add another important restriction to assessing the socio-cultural environment in that they usually only involve the primary caregiver and the infant, while at home they would also be interacting with further caregivers and siblings. Further, home environments contain a multitude of settings that include potential for interaction and joint attention, like feeding, grooming and book reading that do not exist in laboratory free play settings (Tamis-LeMonda, Custode, Kuchirko, Escobar, & Lo, 2018).

Infant pointing has traditionally been assessed either using naturalistic observations (Carpendale & Carpendale, 2010), free play paradigms (R. Brooks & Meltzoff, 2008; Kishimoto et al., 2007), the decorated room (Liszkowski et al., 2012) or through experimental elicitation, usually through an experimenter presenting objects to the infant out of their reach (Begus & Southgate, 2012; Butterworth & Morissette, 1996; Cameron-Faulkner et al., 2015; Cochet & Vauclair, 2010). The last measure, while adequate at eliciting points, lacks any dialogical structure and parent input cannot be measured at the same time. The decorated room, through its design is very well equipped at eliciting pointing and initiating caregiver-infant dialogue, since parents and infants are instructed not to touch any of the objects in the room, while also allowing for unstructured interactions between the caregiver and the infant. Puccini, Hassemer, Salomo, & Liszkowski, (2010) compared gesture use in two settings, free play and the decorated room and were able to show a higher frequency of pointing both from the infants and the caregivers in the decorated room. The best answer might be a mixed methods approach using semi structured situations like free play, or the decorated room and including natural observations as well as measuring infant competence using reliable experimental measures longitudinally by starting testing before the expected ages of emergence of the measured competences to be able to make meaningful predictions and track the intra-individual development of infants’ communicative abilities.

3. AIM AND OUTLINE OF THESIS

Gestural communication, referential understanding and language are necessary for a healthy development. All three abilities are developmentally linked and there is some evidence for socialization influences on all three. Although socialization research is plentiful, less is known about its influence on cultural learning skills during the first two years of life. This thesis, over three chapters, will determine whether different socialization patterns drive the very emergence of cultural learning skills, in particular gestural communication, focusing on the index-finger pointing gesture, referential gesture comprehension, and language comprehension and production. It will further trace the development of these abilities and investigate their developmental interrelatedness.

The first empirical chapter is concerned with the development of referential point comprehension and the influence of interactional experiences in the form of pointing. I will establish when the ability to understand a referential pointing gesture develops and that it is a gradual development predicted by interactional experiences.

The second empirical chapter dives into the ontogeny of index-finger pointing. Testing several intra-individual predictors like the ability to follow a simple pointing gesture, the ability to use showing and whole-hand pointing gestures as well as the influence of parental pointing on the age of emergence of index-finger pointing. I will show that both intra-individual factors like point following, showing and whole-hand pointing as well as parental pointing, before infants themselves are able to point, are predictors of index-finger pointing.

The third empirical chapter will expand on the results of the second chapter by sampling different interactional input from diverse socio-cultural groups (German and Turkish migrant families) like parental pointing but also including other deictic input as well as parental responsivity and comparing their influence on the onset of index-finger pointing. I will also show that different methods of sampling interaction lead to disparities in parental behaviors and some settings are better able to adequately measure infant's communicative competence. I will also map the longitudinal interrelatedness of interactional experiences, index-finger pointing and language development. Throughout all three chapters, I will highlight the importance of socialization on these key cultural learning skills.

4. ONTOGENETIC EMERGENCE OF COGNITIVE REFERENCE COMPREHENSION[1]

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4.1 Abstract

The current study investigated the emergence of point comprehension to occluded objects as a test of cognitive, preverbal referential expectations, in relation to social interactions of infants and parents. In a longitudinal design, infants were tested monthly from 10 to 13 months of age on their ability to find a toy that was hidden in one of two locations. The hiding location was discerned by a communicative pointing act. Correct responses were coded when the infant uncovered the toy at the indicated location to retrieve the hidden object. In addition, caregiver and infant pointing was assessed in a structured situation in which the dyad explored decoration items in a room for 5 minutes. Results were a linear increase of point comprehension, with clear above chance performance emerging around 12 months. Individual stability emerged in month-to-month correlations between 12 and 13 months. At 13 months, half of the sample revealed above-chance competence on the individual level. Point comprehension was synchronously related to infant pointing at 12 months of age. However, point comprehension was not predictive of infant pointing or caregiver pointing. Instead, parent pointing and infant pointing were longitudinally predictive of point comprehension. Findings refine cognitivist views, showing that cognitive referential expectations are not causal to the emergence of caregiver-infant pointing but instead emerge through social-interactional experiences, revealing that social interaction processes influence cognitive development already in the first year of life.

4.2 Introduction

Referential communication requires understanding what a sender intends to communicate about. The understanding of referential intentions lays the ground for word learning in the second year of life (e.g. Akhtar, Carpenter, & Tomasello, 1996; D. A. Baldwin, 1993). In the first year of life, infants already follow adults' attention and adults' non-verbal gestural expressions of reference. Of question, however, is whether and when in the first year of life these early responses to gestural reference begin to entail cognitive referential expectations about an intended referent as opposed to reflecting simpler forms of spatial orienting or action-object associations. Relatedly the question is by which ontogenetic process these cognitive referential expectations may emerge.

Unraveling the emergence of referential understanding is informative to differing theoretical views on cognitive development. Cognitivist views posit that a social-cognitive understanding of others' referential intentions is not just an integral part, but rather cause of the emergence of prelinguistic referential behaviors, like pointing gestures around 12 months of age (e.g., (Csibra, 2010; Tomasello, Carpenter et al., 2007). Interactionist views rather suggest that cognitive understanding emerges through interactional experiences (for an overview, see Moore & Barresi, 2017), such that a cognitive understanding of others' referential intentions may rather emerge as a consequence of social interactions (Carpendale & Lewis, 2006).

One line of evidence, typically taken in support of the former view, shows that, depending on the paradigm and measures, infants follow others' attention-directing behaviors, like pointing, head-turns, or gaze-switches within months after birth, clearly before they begin to point and direct others' attention (for priming and cueing paradigms, see Bertenthal et al., 2014; Deligianni, Senju, Gergely, & Csibra, 2011; Farroni, Johnson, Brockbank, & Simion, 2000; Farroni, Mansfield, Lai, & Johnson, 2003; Hood, Willen, & Driver, 1998; Rohlfing, Longo, & Bertenthal, 2012; for behavioral interactive paradigms, see Adamson & Bakeman; D'Entremont et al., 1997; Flom, Deák, Phill, & Pick, 2004). These findings of early attention-following and spatial cueing, however, may be interpreted on a sub-referential level, on which infants' attention is simply driven to a spatial direction but infants have no prior referential expectations that the gesturer intends to refer to something. The object oriented to may then get linked to the action or actor. Studies using Violation-of-Expectation (VoE) methods and looking time measures have tested whether infants relate the pointing gesture at all to an object, with positive findings at 12 – but not 9 months of age (Woodward & Guajardo, 2002), or at 9 months of age (Krehm et al., 2014) (for gaze: at 12 months, see Paulus, 2011; Woodward, 2003). This line of VoE-research suggests that once infants follow attention to an indicated direction, they then associate the encountered visible object with the gesturer.

Because most of these paradigms typically present young infants with the attention-directing cue and a visible target object, or employ a very short stimulus onset asynchrony, it is difficult to decide between interpretations which invoke spatial orienting or cue-object associations on the one hand, and cognitive referential object expectations on the other hand. One solution is to separate perception from cognitive expectation, as in occlusion paradigms. If infants follow an adult's attention-directing gesture with an understanding of their referential intention, then they should expect a referent object even when it is occluded at the moment of reference. Indeed, by 12-months, infants are surprised when no object is revealed at a referenced location, as indicated by longer looking times (Csibra & Volein, 2008), larger pupils (Pätzold & Liszkowski, 2019), and search for a hidden object (instead of just looking at the occluder; Behne et al., 2012; Liszkowski & Tomasello, 2011). The interpretation of a cognitive referential understanding at 12 months is further re-assured by the finding that infants' correct search for a referred-to, hidden object correlates with their own ability to point to hidden objects (Behne et al., 2012; Liszkowski & Tomasello, 2011; see also Woodward & Guarjero, 2003).

How should we interpret the developmental directionality of the synchronous correlation between referential point comprehension and production at 12 months of age? One study (Csibra & Volein, 2008) suggests that even 8-month-old infants, who do not yet point, have referential expectations, as revealed by longer looking times in a VoE occlusion paradigm. This finding supports the view of a primacy of referential expectations for gestural reference to emerge. However, in their study the analyses included 12-month-olds, and were not independently confirmed for the 8-month-old group. A recent study using a pupillometry VoE occlusion paradigm finds referential understanding at 12- but not 8-months of age (Pätzold & Liszkowski, 2019), which may support the view that referential expectations are rather an emergent skill toward the end of the first year. Thus, more developmental data is needed to pinpoint the timing and process of emergence of infants' cognitive referential expectations before 12 months of age. This requires a longitudinal design to test for relations and their directionality between reference comprehension and production in the first year of life.

In the current study, we therefore tested infants monthly from age 10 to 13 months on their understanding of referential intentions in a hiding game, a paradigm previously established to yield positive results in infants at 18-, 14-, and 12-months of age, with synchronous developmental relations to point production, revealing convergent validity (Behne et al., 2005; Behne et al., 2012). The behavioral demands of searching are well within infants' motor repertoire in the first year of life, as attested by the extant literature on infants' object search (e.g., Marcovitch & Zelazo, 1999; Topál, Gergely, Miklósi, Erdohegyi, & Csibra, 2008). In addition, as part of another longitudinal study not reported here, we assessed infants' and their parents' pointing at each session in a lab-based situation akin to an exhibit, a paradigm which has previously been shown to reliably elicit spontaneous, uninstructed pointing from parents and infants (Liszkowski et al., 2012; Liszkowski & Tomasello, 2011). From a cognitivist perspective, if infants younger than 12 months indeed comprehend referential intentions as some findings suggest (e.g., from 8 months on, see Csibra & Volein, 2008), then infants should reveal this competence on our first assessment at 10 months of age, with no meaningful differences between 10-to-13 months, and intra-individual stability between months. And if reference comprehension indeed preceded point production causally, we should also find predictive developmental correlations from referential point comprehension to point production. On the other hand, from an interactional perspective, if referential point comprehension is a developing skill and not firmly established before 12 months of age, we should find significant developmental increase in performance between 10 to 13 months of age, and intra-individual stability emerging only toward the end of our assessments. And if interactional experiences are indeed a driving force of referential understanding, then infants' emerging pointing skills, and perhaps parents' own pointing for their infants, should predict the development of referential point comprehension.

4.3 Method

4.3.1 Participants

Thirty-one infants (16 girls, 15 boys) were repeatedly tested on a point comprehension test at the ages of 10, 11, 12 and 13 months as part of a larger longitudinal study. Participation and inclusion (see coding section) varied for each month. One child was excluded from all analyses because it participated only once. Table 1 displays the sample characteristics for each month as well as for the within-subject comparison across all months. Infant-parent dyads were recruited in a medium-sized city in the Netherlands via the birth register of the city hall. Dyads participated voluntarily and infants received a small gift after each session.

A session was excluded when the infant became fussy or started crying, when three or more trials were invalid (error trials)[2], or when the infant showed *no search*-behavior more than three times in a row, as indication of distraction and not following the task. Table 1 gives an overview of the number of infants participating per month, the reasons for missing data points and the number of valid trials and error trials.

Table 4-1. Number of participants and valid trials per month.

age	*N*	missing	Reason	gender m/f	total trials	error trials	valid trials
10	25	6	did not participate (2) excluded (4)	15/10	150	5	145
11	26	5	did not participate (3) excluded (2)	13/12	156	2	154
12	27	4	did not participate (2) excluded (2)	13/13	162	0	162
13	27	4	did not participate (4)	14/14	162	4	158
Infants who were included in every session N=17							

Infants were sitting on one side of a table on their parents' lap facing the experimenter (E) on the other side of the table. Eight different small plastic toys, (*approx.* 3 cm high) were stored under her table (one for each trial). On the long ends of a self-made cardboard board (80x20cm), were two containers (12 × 30 cm) attached, about 55cm cm apart from each other. The short side walls of the containers were higher at E's end and lower at the infant's end, and the top was cut

[2] Invalid trials were either experimenter errors (e.g. object location was visible during hiding) or trials were the infant did not participate (i.e. crying, leaving the table etc.)

off. The bottom was padded with foam to absorb potential sound when E placed a toy inside. Two same-colored clothes (30x30cm) of 8 differently colored pairs (one for each trial) were used to cover the containers and occlude infants' line of sight into the containers. Four cameras recorded the scene; two focusing on the infant, and two focusing on the experimenter.

4.3.2 Procedure

As part of a larger longitudinal project, all included infants first participated in the 'decorated room' procedure (Liszkowski et al., 2012). Parents were led into a room decorated with various standardized items and instructed to carry their infant on the hip and have a look at the decoration items with their infants. We recorded the uninstructed, spontaneous rates of parent and infant pointing in the room for 5 minutes. Then infants participated in the point comprehension task which was preceded and followed by various other tasks not reported here. The procedures were identical for each month. The point comprehension test followed the procedure by Behne et al. (2012) and consisted of two phases.

2.3.1 Warm-up. The warm-up phase served to familiarize the infant with the game. In the very first trial, E presented the toy by moving it and then held it up with one hand, making sure the infant was attentive. E overtly put it in one of the two containers, saying "Kijk, hier leg ik hem neer" [*Look, I put it here*] and then slid the board towards the infant to let her retrieve the toy. In the second warm-up trial, E covered one of the two containers with a cloth. He presented a new toy in the same way, saying "Nu ga ik de [X] verstoppen" [*Now, I'm going to hide the [X]*], and put it under the cloth in the container. Again, she slid the board towards the infant and said "Zoek maar" [*Search for it*]. If the infant did not search immediately, E encouraged her by saying "Waar is de X?" [*Where is the X*?]. If the infant did not search in the right place, the second warm-up trial was repeated once. Then, the test phase started. Percentages for successful completion of warm-up trials, i.e. correct searching in the last warm-up trial, were: at 10 months– 80%, at 11 months – 76%, at 12 and 13 months– 100%.

2.3.2 Test phase. E covered both containers with a cloth. E then presented the toy in the same way as in the warm-up trials. She then held up the toy with both hands, closed her hands around the toy, and moved them under the table. There, she transferred the toy into the fist of one hand and then slid both hands under the cloths of the containers, covertly depositing the toy in one of them. She pulled her empty hands back and presented them to the infant. E called the child's name and establishing eye contact and then pointed and looked to the hiding location. She pointed contra laterally with the extended index-finger roughly at the midline of her body (see Figure 4-1).

Figure 4-1. Set up of the study

While pointing to the hiding location, she slid the board over to the infant. For the first 5 sec. after establishing eye contact E only looked at the child in a communicative ostensive manner (raised eyebrows, big eyes) while holding her hand roughly at the midline of her body with the extended index-finger pointing towards the hiding location. After the 5 sec. (if the child had not found the toy by now), E again called the child's name, establishing eye contact and now, in addition to pointing, she also looked at the hiding location (incl. turning her head that way, but without strong ‘nodding’ in that direction) and back at the child. If the infant did not respond after 15 seconds, E uncovered the toy and let the child retrieve it. She then pulled back the board and switched the pair of cloths. In total, the test phase consisted of six trials. The hiding locations were counterbalanced (items were hidden on the same side twice two times during one session). The experimenter always pointed towards the location where the object was hidden.

4.3.3 Coding and analyses

Behaviors were coded offline from the video recordings with the freely available software ELAN (Version 4.9.1; Wittenburg, Brugman, Russell, Klassmann, & Sloetjes, 2006). Table 4-2 displays the coding categories for the point comprehension paradigm based on previous studies (Behne et al., 2005; Behne et al., 2012). In addition to coding the side at which infants removed the cloth from the box, we also coded whether infants actually took (or attempted to take) the toy from the box as a more conservative indication of actual search for the toy.

Table 4-2. Coding categories for infants' searching response

correct search (cloth + object)	The infant removed the cloth at the indicated side and took or attempted to take the toy (i.e. removed the cloth in order to take the toy).
incorrect	The infant removed the cloth at the other side first. If the child took both cloths at the same time without orientation towards one side, this was coded conservatively as incorrect.
no search	The infant did not react or did not take any cloth. Trials where the infant lifted the cardboard were also coded as no search.
invalid trial	Experimenter’s errors and other interruptions, e.g. if the child started crying or left the parents’ lap.
perseveration	A trial was coded as perseveration if the infant searched in the same location as in the last valid trial

The first 19 subjects were coded by rater A. Rater B rated the next 12 subjects. To assess inter-rater reliability between the two, the data of three infants per month (i.e. 12 sessions, 16% of data) rated by rater A were randomly selected and recoded by rater B. Reliability with agreement of all response codes was very good (Cohen's Kappa = .85).

In the 'decorated room' all pointing gestures by parents and infants were coded, and coding included the shape of the pointing gesture (whole-hand, index-finger point and unclear if shape could not be ascertained). In order for a gesture to be coded as a point the arm had to be at least half way extended towards a perceptible object, without clear postural indications of attempting to touch or reach for it (e.g., leaning forward; whining; grasping). For a point to be considered an index-finger point the index-finger had to be distinctly extended relative to all other fingers; when this was not the case the point was coded as a whole-hand point. To assess inter-rater reliability for the decorated room, 12 sessions, i.e. 15% of data, were randomly selected from the first 20 subjects and recoded by rater B. Reliability with agreement of all response codes was very good (Cohen's Kappa =.83). The age of emergence of index-finger pointing was defined as the first month in which the infant clearly pointed at least twice with the index-finger.

The statistical analyses were conducted using SPSS (Version 21.0). In our analyses of the point comprehension task, we first compared target vs. distractor choices across ages (repeated measures Anova), and then for each age separately (paired t-tests). For control analyses we tested whether performance across age was affected by perseveration tendencies to keep choosing one side (repeated measures Anova with performance vs. perseveration across age), and whether it was affected by learning across repeated trials. Next, we tested at what ages infants at a group level searched for the toy at the indicated side above chance (one-sample t-tests). Then, we looked at individual competence by testing for above chance performance across trials (i.e. at least 5 trials correct) at each age (binomial tests). Finally, as an indication of stable individual competence, we tested for month-to-month correlations on our measures of performance.

To analyze the relations between point production and point comprehension, we first looked for concurrent relations between infant point comprehension and production at 12 months, as reported in previous literature (Behne et al., 2012); Liszkowski & Tomasello, 2011). We then looked for predictive relations in both directions for production and comprehension by testing whether competence in one skill at earlier months (e.g., 10, 11 months) would predict competence in other skills at later months (e.g., 12, 13 months). Due to the relatively small sample size, correlation analyses were run using the Monte Carlo permutation model (based on 10.000 sampled tables) and checked for outliers. In addition, we conducted dichotomous (e.g. median split) analyses, to reduce noise in the variances.

4.4 Results

4.4.1 Target – Distractor analyses

To test whether there were differences in the accuracy of correct versus incorrect search behavior, we conducted a 2 (search: correct cloth & toy, incorrect search) x 4 (age groups) repeated measures ANOVA on the mean number of trials (N=17). A main effect of search revealed significantly more correct than incorrect searches, $F(1,16)= 56.35$, $p< .000$, $\eta_p^2=.779$. There was no effect of age but the linear interaction term between age and search became significant, $F(3,14)= 3.12$, $p= .034$, $\eta_p^2=.163$, revealing a significant linear increase in infants' accuracy across the three months. Table 4-3 displays the results of the pairwise comparison between correct searches and incorrect searches for each month. At each month, infants searched significantly more often for the toy in the indicated compared to the distractor location.

Table 4-3. Results of paired t-test: Comparison of means for correct and incorrect search

age (months)	*N*	correct trials		incorrect trials		t-test				
		M	*SE*	*M*	*SE*	Mean difference	95% Cl for Mean Difference	*t*	*df*	*p*
10	25	2.64	.29	1.56	.18	1.08	.45-1.7	3.540	24	.003
11	26	3.58	.35	1.42	.28	2.15	1.06-3.25	4.055	25	<.001
12	27	3.56	.31	1.33	.23	2.22	1.32-3.13	5.036	26	<.001
13	27	4.19	.26	1.37	.24	2.81	1.83-3.80	5.858	26	<.001

To analyze whether perseveration tendencies to search at the same location as in the trial before interacted with correct searching, we ran a second set of analyses. A 2(search: correct cloth & toy, incorrect) x 2(perseveration: same, different side) x 4 (age groups) repeated measures ANOVA revealed significant main effects of age (F(3,14)=3,49, p=.042, $\eta_p{}^2$=.41) and search (F(1,16)=68,83, p=.00, $\eta_p{}^2$= .80) and the expected two-way interaction between age and search (F(3,14)= 3,80, p=.033, $\eta_p{}^2$=.432). Further, perseveration and search interacted (F(1,16)=.24,94, p=.00, $\eta_p{}^2$=.59), such that mean differences between correct and incorrect search were larger when there was no perseveration (mean difference = 1,91) than when there was perseveration (mean difference = 0,77), although both differences remained highly significant (p’s < .001). Thus, while perseveration influenced search performance, this did not affect correct search performance, and the perseveration effect was not age specific (interaction term of perseveration by age: F(3,14)=1.782, p=.192, $\eta_p{}^2$=.264).

To examine potential learning effects, a repeated measures ANOVA (n = 17) with age (10, 11, 12, 13 months) and trials (first half of trials, second half of trials) as within subject factors and number of correct searching trials as dependent variable was conducted. The analysis revealed a significant effect for age (*F*(1.16) = 7.06, p = .035, η_p^2 = .192, Greenhouse-Geisser corrected), but no significant effect of trial (*F*(1, 16) = 0.122, p = .731, η_p^2= .008), and no interaction effect between age and trial (*F*(3, 14) = 1.73, p = .206, η_p^2= .271). Thus, performance was not due to learning across trials.

4.4.2 Chance-level analyses

Table 4-4 displays the results of infants searching for the toy at the correct location compared to chance. Chance was at 0.5, and trials in which infants did not search at all were excluded. At 10 months, infants performed at chance. Clear and highly significant above chance performance emerged at 12 and 13 months.

Table 4-4 Results of one-sample t-tests: Infants' mean correct search behavior (cloth & toy) across trials (compared to chance level (.5)

age (months)	*n*	correct trials		t-test				
		M	*SE*	Mean difference	95% Cl for Mean Difference	*t*	*df*	*p*
10	24	.53	.045	.03	-.07-.01	.59	23	.557
11	25	.61	.059	.11	-.01-.24	1.92	24	.067
12	26	.68	.048	.18	.08-.27	3.7	25	.001
13	27	.72	.041	.22	.13-.31	5.27	26	<.001

Since we could not be sure why infants did not search in some trials, either because they did not understand the game or because they were not motivated to participate we ran the same analyses using a less conservative approach. We excluded all trials during which infants did not search. Results can be found in table 4-5. Infants performed above chance from 10 months onwards.

Table 4-5 Results of one-sample t-tests: Infants' mean correct search behavior (cloth & toy), not including "no search" trials across trials, compared to chance level (.5)

age (months)	*n*	correct trials		incorrect trials		t-test				
		M	*SE*	*M*	*SE*	Mean difference	95% Cl for Mean Difference	*t*	*df*	*p*
10	25	2.64	.29	1.56	.18	1.08	.45-1.7	3.540	24	.003
11	26	3.58	.35	1.42	.28	2.15	1.06-3.25	4.055	25	<.001
12	27	3.56	.31	1.33	.23	2.22	1.32-3.13	5.036	26	<.001
13	27	4.19	.26	1.37	.24	2.81	1.83-3.80	5.858	26	<.001

4.4.3 Individual level competence

We assessed infants' performance at each age on an individual level. This analysis included only infants who had searched in at least 5 trials. Infants who searched correctly above chance on at least 5 trials (one-tailed binomial test) were categorized as "comprehenders". Figure 4-2 displays the percentage of comprehenders across age groups.

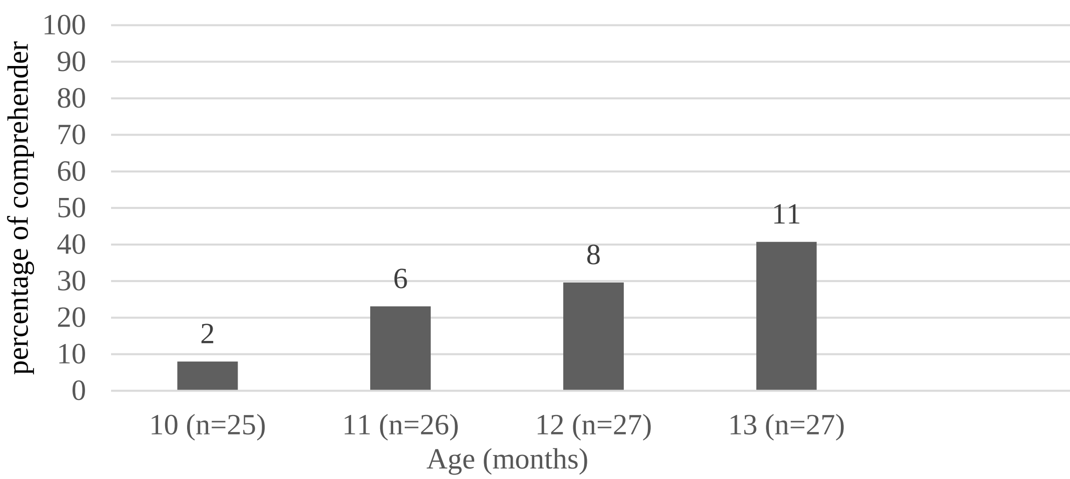

Figure 4-2. Percentage of Comprehender

Note. Binomial test. "Comprehenders" searched correctly in at least 5 trials, There were significantly less comprehenders than non-comprehenders at 10 months (binomial, *p*'s= .001). By 13months, about half of the sample included comprehenders.

4.4.4 Stable competence across months

To test for individual stability in performance across months, we ran month-to-month correlation analyses on the difference scores of correct searches relative to incorrect searches ([correct toy search – incorrect search] / [correct toy search + incorrect search]). Individual stability of performance emerged from 12 to 13 months ($r(25)= .595$, $p=.004$), but not earlier. A similar pattern also emerged on the individual level. The number of comprehenders between 12 and 13 months was correlated, $\phi(25)= .359$, $p=.037$, one-tailed, but not earlier. Stable competence thus emerged first around 12 months.

3.5 Synchronous relations between pointing and point comprehension

We analyzed concurrent relations between infant point comprehension and infant point production at 12 months of age, to test for reproducibility of findings previously reported in the literature. In addition, we looked for a concurrent correlation between parent pointing and infant point comprehension. Infant index-finger pointing was concurrently correlated with point comprehension at 12 months ($r(26)=.482$, $p=.015$), but not earlier. This relation was not apparent for infant hand pointing at 12 months ($r(26)=-.178$, $p=.396$), or earlier. Parent pointing was not concurrently correlated with infants' point comprehension at any month.

4.4.5 Predictive relations between pointing and point comprehension

First, we analyzed whether infant point comprehension predicted infant point production, and perhaps parent pointing. Second, we looked at the opposite directions and analyzed whether point production by infants and parents was predictive of infants' point comprehension. Regarding the former, point comprehension at 10, 11 or 12 months did not correlate predictively with infant index-finger pointing frequency at 11, 12 or 13 months (all p's > .105), or with the age of emergence of becoming an index-finger pointer (respectively, p's > .194). Further, median split correlations between above median performance in point comprehension and index-finger pointing were not significant at any age (all p's > .219). Neither did age of emergence of becoming a point comprehender predictively correlate with the frequency of infant index-finger pointing at 12 or 13 months (all p's > .485). The pattern of non-significant relations was similar for hand pointing and pointing overall. The only significant predictive relation between point comprehension and infant pointing was negative and emerged late: At 11 months, point comprehension correlated negatively with infant hand pointing at 12 months (r(24)=-.446, p=.029). This correlation remained significant when controlling for index-finger pointing at 12 months (partial r(22)=-.440, p=.035).

Further, point comprehension at 10, 11 or 12 months was not predictive of the frequency of parental pointing at 11, 12 or 13 months (all p's>.283). A median split correlation revealed a weakly significant association between infants who were "Comprehenders" at 11 months and parents who pointed above the median at 13 months (ϕ(26)=.422, p=.043), although this single association is difficult to interpret given that parent pointing did not dramatically change across months and was highly inter-correlated between months (all r > .739, all p < .001).

In contrast, regarding predictions in the opposite direction, infant index-finger pointing at 11 months correlated predictively with point comprehension at 12 months (r(24)=.467, p=.022). The relation remained significant when controlling for infant index-finger pointing at 12 months (partial r(22)=.439, p=.041). Median split correlations further confirmed that infants at 11 months who pointed with the index-finger above the median of their group were also more likely to be a comprehender at 12 months (ϕ (24)=.418, p=.041). Hand pointing was not predictive of point comprehension in any of these analyses (all *p*'s > .391). Further, parental pointing was predictive of point comprehension. Median split correlations revealed a significant predictive association between above-median parental pointing at 10 months and above median infant point comprehension at 12 months (ϕ(25)=.335, *p*=.041, one-sided) and 13 months (ϕ(23)=.318, *p*=.008). Applying a partial correlation analyses by controlling for infant pointing at 12 months, the relations remained significant (respectively, *rho(par)*= 404, *p*=.04; rho(par)=.491, p=.007).

4.5 Discussion

The current study investigated when in the first year of life infants begin to comprehend referential pointing to perceptually occluded referents. Further, the study investigated whether interactional skills and experiences in the form of infant and parent pointing are developmentally related to point comprehension, either as consequence or predictors.

In regards to the first question, the developmental timing of reference comprehension, one finding was that there was already some competence at 10 months, the earliest age we tested. Competence, however, increased linearly with age and was about 2.5 times higher three months after the first assessment. Further, 10-month-olds searched not differently from chance, and clear and highly significant above chance performance emerged first at 12 months. On an individual level, competence was rather low in the first year of life, while by 13 months about half of the sample performed individually above chance. Finally, search performance was uncorrelated across the first assessments and became stable first between 12 and 13 months, as revealed by strong and highly significant correlation on the level of mean performance as well as individual competence. Our control analyses suggest that perseveration did not account for the developmental increase, making it unlikely that younger infants' performance was hampered by extraneous task demands. Further, conditional learning, e.g. that infants learned the relation between the point and the hidden toy during the session after first finding the toy by coincidence, cannot account for the main findings, because there were no learning effects across trials.

Where does this leave us with regard to the developmental timing of point comprehension? A cognitive view (e.g. Csibra, 2010) and previous findings (Csibra & Volein, 2008) would suggest that infants have referential expectations already in the first year of life, around 8 months or earlier. On this account, we would have expected in the current study clear competence at 10 months of age, as indicated by above chance search performance, intraindividual stability across months, and no substantial, meaningful increase of competence over the following weeks. The current results do not support this view. While there was evidence for some early competence, this early competence did not yield above chance search, it developed substantially over time, and it became stable only at the end of infants' first year of life, with individual level competence in only half of the sample by 13 months of age. The picture revealed here is thus one of a developing ability toward the end of infants' first year of life. A developmental view is also consistent with findings by Behne et al. (2005) who showed that individual-level competence still increased from 18 to 24 months of age. Thus, while simpler forms of attentional orienting and social cueing are present early in the first year of life (e.g., Bertenthal et al., 2014), and enable to associate looker and object (e.g., Paulus, 2011; Woodward, 2003), the current study shows that gestural reference comprehension to occluded entities, as a litmus test for cognitive referential expectations, emerges only toward the end of the first year of life (see also Paetzold & Liszkowski, in press).

In regards to developmental factors relating to point comprehension, one finding was a synchronous relation by 12 months of age between infants' point production and point comprehension. This result reproduces earlier findings of synchronous relations at 12 months (Behne et al., 2012; Liszkowski & Tomasello, 2011; see also Woodward & Guajardo, 2002). The unified competence of referential skills in comprehension and production at 12 months of age suggests against independently emerging abilities and a prolonged emergence of reference skills across the second year of life (Carpendale & Lewis, 2006; Moore & D'Entremont, 2001), instead supporting a 'rich' social-cognitive account of preverbal referential communication at 12 months of age (Liszkowski, 2018).

Interestingly, poorer performance on point comprehension at 11 months predicted more hand pointing at 12 months. This is in line with results showing that the synchronous correlation between point comprehension and production at 12 months is specific to index-finger pointing, not to whole-hand pointing (Liszkowski & Tomasello, 2011), and it relates to the finding of a negative relation between hand pointing at 12 months and vocabulary size a year later (Lüke et al., 2016; Lüke & Ritterfeld, 2014).

Regarding the developmental directions between point comprehension and point production, we found that point comprehension was not predictive of the emergence or development of infant pointing on any of our measures. Neither was infant point comprehension meaningfully predictive of parents' pointing for their infants. While the absence of evidence cannot reveal evidence for absence, the lack of predictive correlations from point comprehension to point production appears meaningful in the presence of synchronous, high correlations at 12 and 13 months of age. Moreover, several correlations in the opposite developmental direction were significant. These findings thus speak against cognitivist views which have suggested that referential expectations about occluded objects (Csibra, 2010), or a deeper mentalistic understanding of referential intentions (Tomasello et al. 2007) are causal for referential pointing to emerge.

Instead, infants' index-finger pointing at 11 months was predictive of point comprehension at 12 months both in frequency and on the level of individual competence (i.e. Comprehender). These developmental relations were not mediated by synchronous correlations at 11 months and remained significant when controlling for the concurrent correlation between index-finger pointing at 12 months of age, substantiating the meaning. Further, parental pointing at 10 months was predictive of infant point comprehension at 12 and 13 months, and remained predictive when controlling for infants' point production at 12 months. These findings are in support of a social-interactional view of development in which infants' experience with parents' use of pointing for them, and infants' skills in referring others to their focus of attention, enable infants to build up cognitive referential expectations. In contrast to previous accounts (Carpendale, Atwood, & Kettner, 2013; Moore & Barresi, 2017) our current results clearly shift the emergence of cognitive referential skills to an earlier age, around 12 months, rejecting the notion of a protracted development. However, current results do provide empirical support for the proposed ontogenetic process in which social-interactional experiences and skills play a pivotal role (see Moore & Barresi, 2017), here in the form of parent and infant pointing, which shape up cognitive expectations about occluded referents early in ontogeny.

Other studies have shown that socialization exerts an influence on basic socio-cultural skills, like helping (Brownell, Svetlova, Anderson, Nichols, & Drummond, 2013; Dahl, Satlof-Bedrick, Hammond, Drummond, & Brownell, 2017) and the emergence of deictic gestures (Salomo & Liszkowski, 2013) in infancy. Our current findings add to the study of the ontogenetic emergence of basic socio-cultural skills, showing that social interaction mediates the emergence of reference comprehension to occluded entities. It is reasonable to assume that a social-constructivist process of cognitive development does not just begin with cognitive reference comprehension at the end of the first year of life but likely also contributes to its very emergence.

5. ONTOGENY OF INDEXFINGER POINTING

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5.1 Abstract

The current study investigated the ontogeny of index-finger pointing using a longitudinal design, testing several potential predictors, infants' showing gestures, infants' hand pointing gestures, infants' ability to follow a simple pointing gesture and parental pointing input. Pointing behaviors of parents and infants was assessed in a structured situation in which the dyad explored decoration items in a room for 5 minutes from 8-13 months, during the same sessions infants' showing gestures were measured during free play sessions and a simple point following paradigm was carried out. A second study was implemented using a cross sectional design to compare parental pointing of parents of 5-6 months old infants and 8-9 months old infants again using the decorated room paradigm from the first study. Concurrent correlation analyses, once all abilities had emerged, showed a common capacity of communication for index-finger pointing, showing gestures and point following while hand pointing with hand pointing being unrelated. Predicting the onset of index-finger pointing, parental pointing, infant hand pointing, showing gestures and point following were found to be significant predictors. Regression analyses showed particular importance of parental pointing for the onset of index-finger pointing. The results of the second study were, parents of younger infants were less likely to use index-finger pointing gestures. Overall, the results speak to a combination model for the ontogeny of index-finger pointing with early social shaping by parents as an important predictor of the onset of index-finger pointing and infants' own referential abilities using deictic gestures like hand pointing and being able to follow a pointing gesture as important cognitive indicators of competence and onset.

5.2 Introduction

Pointing directs others' attention for communicative purposes and while it can take many diverse forms from lip pointing to head pointing (Enfield, 2009; Liszkowski et al., 2012; Salomo & Liszkowski, 2013) using the extended index-finger to point seems to be a universally occurring gesture (Liszkowski et al., 2012; Salomo & Liszkowski, 2013; Veena & Bellur, 2014) that is exclusive to humans (Liebal & Tomasello, 2009).

Infants usually learn to use the index-pointing gesture between 11 and 12 months; (Butterworth & Morissette, 1996; Capone & McGregor, 2004; Colonnesi et al., 2010; Iverson et al., 1994; Iverson & Goldin-Meadow, 2005; Leekam, 2016; Lock et al., 1990; Osterling & Dawson, 1994; Rowe & Goldin-Meadow, 2009b; Sauer et al., 2010). However congenitally blind children, while they use other gestures, do not point for others (Iverson & Goldin-Meadow, 1997, 1998). Also, children with ASD (autism-spectrum disorder) use fewer or no index-pointing gestures and it is used as an early developmental indicator of ASD (Baron-Cohen, 1989a; Goodhart & Baron-Cohen, 1993; Leekam, 2016; Osterling & Dawson, 1994; Stone et al., 1997, 1997).

Index-finger pointing is an important developmental achievement and has been shown to be particularly important for language development (Butterworth & Morissette, 1996; Capone & McGregor, 2004; Cochet & Byrne, 2016; Colonnesi et al., 2010; Iverson et al., 1994; Iverson & Goldin-Meadow, 2005; Mumford & Kita, 2016; Rowe & Goldin-Meadow, 2009b; Sauer et al., 2010). Lüke, Grimminger, Rohlfing & Liszkowski (2017) found that the use of the index-finger gesture at 12 months (instead of using whole-hand pointing) was predictive of whether infants qualified as language delayed when they were 24 months old. Similarly Murillo & Belinchón (2012) found index-finger pointing use at 12 months to be the best predictor of infants' vocabulary at 15 months.

Even though the importance of the development of index-finger pointing is undisputed we still know little about its ontogeny. There are varied accounts on the ontogeny of index-finger pointing, mostly emphasizing one of two aspects, the first being the importance of social input or social shaping accounts, the other being the necessity of prior development of social processing or social cognition accounts.

The social shaping accounts assert the importance of the socialization of infant's pointing gestures through parental reactions (Delgado, Gómez, & Sarriá, 2009; Masataka, 2003). For example Carpendale & Carpendale (2010) observed pointing for non-communicative reasons, which was then socialized by parental reactions, in their diary study following the development of one infant. One of the early accounts on the ontogeny of pointing was the that pointing actually comes from reaching (Murphy, 1978). In line with this are observations that parents tend to comment on their infant's points (Kishimoto et al., 2007).

The social cognition accounts posit that in order to use the index-finger pointing gesture infants require the understanding of others 'attention, need to be motivated to take part in social interactions and need to be able to share others' intentions (Butterworth, 2003; Cochet & Vauclair, 2010; Leroy, Mathiot, & Morgenstern, 2009; Leung & Rheingold, 1981; Liszkowski & Tomasello, 2011; Matthews et al., 2012). In line with these accounts, we know that infants already possess at least parts of these skills when they begin to point at 12 months (Carpenter et al., 1998).

While seemingly contrary at first glance, these accounts are not necessarily incompatible. In order to make sense of the social input infants' receive, social cognition is necessary. At the same time, increasing social input might in turn increase social-cognitive skills. Longitudinal studies by design are especially suited to highlight the interplay of these two factors.

So what are the empirical findings on the ontogeny of index-finger pointing? While quite a few studies have looked at the predictors of the frequency of pointing once it is established, few have looked at the onset of index-finger pointing.

From a social shaping point of view one important predictor of pointing onset is parental input, especially parental pointing. In a cross-sectional study of infants aged 8-15 months, (Salomo & Liszkowski, 2013) found no correlation between the amount of parental pointing and the onset of infants' Index-finger pointing. So far, empirical findings seem inconclusive both supporting and questioning the importance of the social input and cross-sectional correlations do not yet imply causality meaning this has to be investigated further.

Infants begin to follow the gaze of another person and begin to alternate their gaze between objects and people at the age of 6 months (Bakeman & Adamson, 1984). While there is no consensus on the age of onset of point following, we know it reliably precedes the onset of index-finger pointing (Carpenter et al., 1998). In the training-study by (Matthews et al., 2012) parents of infants aged 9, 10 or 11 months were shown how to increase pointing for their infants and instructed to use these methods for 15 minutes every day. Parental pointing was also observed during a free play session and infants were tested for gaze following. Infants' ability to use a pointing gesture at the end of the sessions one month later (so either at 10, 11 or 12 months of age) was not affected by training but predicted by the infant's ability to gaze follow. Neither was the frequency of pointing which was predicted by maternal pointing during free play and gaze following. While these are interesting results infants' pointing development was only observed for one month which meant only 60% of infants in the study were actually able to use an index-finger gesture and also, during the first visit about 20% of infants were already using the index-finger gesture. Contrary to Matthews et al. (2012), Rowe & Leech (2018) implemented a similar design, also instructing parents to play with their infants for at least 15 minutes each day, pointing as much as possible during that time, reminding parents weekly, over a period of two months (between age 10-12 months). They collected data at 12, 14, 16 and 18 months. In their study, both parents' and infants' frequency of pointing gestures increased due to the training, which was already apparent at 12 months. While the results of the second training study are promising in regards to the influence of caregiver input on infant pointing, the intervention started at an age where some infants were already able to point and only targeted overall frequency of pointing.

In order to investigate the ontogeny of index-finger pointing, testing should commence before infants are actually able to use a pointing gesture (at 8 months of age), and include a longer developmental period. Also, free play is not the best context to study parental pointing input since while interacting with objects in close contact with the infant, few pointing gestures are used (Puccini et al., 2010).

Should it be true that both the social input and social cognition are interrelated with index-finger pointing across infant development we would expect to find further interrelations once these abilities have emerged in the fidelity and frequency of use.

Evidence of the influence of parental pointing on the frequency of index-finger pointing has been found in a number of studies. Matthews et al., 2012) showed a positive correlation between the frequency of parental index-finger pointing during free play and the frequency of infants' index-finger pointing at 12 months. Similarly Ger et al., 2018) showed that caregivers' contingent reactions to pointing (including moving towards the object and naming the object) at 10 months predicted pointing frequency at 12 months.

We know the ability to follow a simple pointing gesture continues to develop even after infants use the index-finger pointing gesture themselves (Deák, Flom, & Pick, 2000; Woodward

& Guajardo, 2002). Ger, Altınok, Liszkowski & Küntay (2018) found a positive correlation between the frequency of pointing at 10 months and the ability to follow a simple pointing gesture at 12 months adding evidence for a possible dialectic interaction between these two abilities. In a study with Japanese infants Kishimoto (2017) also showed a positive correlation between caregivers' contingent pointing (index-finger pointing 6s after the infant's point) and the frequency of infants' Index-finger pointing 7 months later.

There is also evidence that using index-finger pointing in turn increases social cognitive skills, showing infants who produce pointing gestures are also more likely to understand pointing gestures (Brune & Woodward, 2007). Ger et al., 2018) found longitudinal evidence, showing that the frequency of index-finger pointing at 10 months and infants' point following at 12 months were positively correlated. Yet other predictors may be seen in developmentally preceding social behaviors in particular hand pointing as well as showing and giving gestures.

One of the first communicative gestures used by infants is reaching for objects which has also been hypothesized as the origin of the index-finger pointing gesture (Murphy, 1978). However, reaching being an imperative gesture cannot explain the declarative content of index-finger pointing. Whole-hand pointing is sometimes considered a reaching gesture (Leavens & Hopkins, 1999; O'Neill, 1996) and not a form of pointing (Franco & Butterworth, 1996; Leung & Rheingold, 1981). However newer studies (Cochet & Vauclair, 2010; Grünloh & Liszkowski, 2015; Liszkowski & Tomasello, 2011) show infants using index-finger pointing and whole-hand pointing during the same point-elicitation paradigm in a way that is clearly distinguishable from reaching gestures. It could be, that hand pointing is simply index-finger pointing without the fine motor skills necessary to selectively extend the index-finger. However, both the fact that infants use this gesture as well as the index-finger gesture during the same session (see above), as well as the fact that whole-hand pointing is not related to other cognitive skills or language (Liszkowski & Tomasello, 2011; Lüke et al., 2016; Lüke et al., 2017) speak against this. Furthermore in a cross-sectional study (Grünloh & Liszkowski, 2015) could show that hand pointing was less coordinated with vocalizations than whole-hand pointing. Despite this, so far whole-hand pointing has not been investigated as a potential predictor of index-finger pointing.

The second group of gestures developmentally preceding the development of the index-finger gesture is comprised of so-called "holdout" (showing) and giving gestures (Ho&Gs). Some of the earliest proto declarative gestures are holding out an object for another person or giving an object to another person (Bates et al., 1975). These gestures are understood as intentioned by the infant to direct others' attention towards an object or occurrence in their environment. Infants start to hold out objects for another person using their extended arm at the age of 9 months (Liszkowski, 2008). Bates et al. (1975) first suggested that showing, giving and pointing gestures were cognitively related. There is also some empirical evidence of Ho&Gs/showing gestures as potential predictors for infants' index-finger pointing. In a longitudinal study, Cameron-Faulkner, Theakston, Lieven & Tomasello (2015) found that the frequency of Ho&Gs at 10 and 11 months correlated with index-finger pointing at 12 months.

5.3 Study 1

In order to disentangle the interrelations of these different predictors and the onset and development of index-finger pointing the current study used a longitudinal design with dense monthly samplings starting when the infants were 8 months old. It could be that the influence of the parental input is found earlier than studied so far (usually at 10 months) preceding the development of most deictic gestures in infants. Both the decorated room measure, a point elicitation paradigm (Liszkowski & Tomasello, 2011) as well as free play sessions during each month were used to analyze infants’ deictic gesture use and parental input. Social-cognition was measured using a simple point following paradigm.

Should the social cognition accounts be true, point following would be best predictor of onset and development of pointing. Should the social input accounts be true parental input (parental pointing) would be the best predictor, with both whole-hand pointing and/or Ho&Gs as potential developmental precursors. However, a more complex account of different influencing factors at different points in the infants’ development might also apply.

5.3.1 Method

The current results are part of a larger longitudinal study. Infants and their parents visited the lab monthly from when the infants were 8 months of age until they were 13 months old.

5.3.1.1 Participants.

31 infants (15 male, 16 female) and their parents from the city of Nijmegen, in the Netherlands took part in the study. One dyad was removed from data analysis because they only participated in two sessions. The infants were recruited from a database of parents who had been initially contacted via the city’s birth register and had shown interest to participate in child development studies. Before participating, parents signed letters of informed consent. After every monthly meeting, a small gift was given as a thank-you gesture.

The mean age of the infants was 259.6 days (*SD* = 7.6 days) for the 8 months session; 292.7 days, (*SD* = 7.3 days) for the 9 months session; 323.4 days, (*SD* = 7.2 days) for the 10 months session; 352.4 days, (*SD* = 7.6 days) for the 11 months session; 381.3 days, (*SD* = 8.4 days) for the 12 months session and 411.8 days, (*SD* = 9.3 days) for the 13 months session.

5.3.1.2 Procedures.

In order to assess the development of infant and parental pointing the “decorated room” procedure (Liszkowski et al., 2012) was used, which is broadly analogous to a museum or exhibit. For the “decorated room” parents and their infants were lead into a room decorated with 20 interesting objects hung on the walls and ceilings, including for example a feather boa, photos of animals, a cup and flowers, and asked to look at the objects with their infant while holding them on their hip and to make sure not to touch any of the items. The scene was recorded by four cameras, each in one corner. Parents were kept blind to the purpose of the study and pointing was never mentioned during any of the sittings.

Directly afterwards the infant’s ability to follow a simple pointing gesture was measured. The experimenter stood facing the infant. Parents were asked to hold their infant in front of their body. At the beginning of each trial the experimenter called the infant’s name and made sure to have eye contact with the infant. She then turned her head to fixate one if the objects either on the right or the left of the infant hanging either in their peripheral field of vision or slightly behind the infant with an excited facial expression while extending her hand to point at the target and exclaiming “oh”. This was followed by one gaze alternation while the arm was extended followed by another gaze alternation after the arm had been retracted. Afterwards the experimenter would wait for 10 seconds before starting the next trial by establishing eye contact and calling the infants name. To eliminate the effects of different directing gestures (see (Flom et al., 2004) and optimise the information from the directing gestures, the current study applied all gestures fluently together (turning the head, looking at the referred object, pointing at it and vocalisation were naturally synthesized). There were four trials, two for each side, starting with the item on the right side, lasting approximately one minute (*M* = 50:33 s, *SD* = 16:05 s). Pointing was always done cross-laterally. Last, parents and infants were asked to interact with toys during a free play setting. There was no specific instruction, parents were simply asked to stay on a blanket that was laid out on the floor and behave as if they were at home. Sessions were recorded using four cameras, on in each corner of the room and lasted five minutes.

5.3.1.3 Coding.

Coding for the “decorated room” was done using ELAN, a free software program developed by the Max Planck Institute for Psycholinguistics, which allows for coding that is time locked with the video data. Based on Liszkowski and Tomasello (2011) coding included both parental and infant pointing gestures. The arm had to be either fully or half way extended toward an identifiable object or location, accompanied by looks in that direction, excluding clear attempts to grab or touch an object, and wiggling movements of the arm due to balancing or position shifting by the parent. Index-finger points were coded when the index-finger was distinctly extended relative to all other fingers, else it was coded as a whole-hand point.

The age of emergence (AoE) of infant index-finger pointing was defined as the first month in which an infant pointed at least twice with their index-finger during that session. This behaviour had to be shown at least two sessions in a row. If an infant pointed at least twice for the first time during the last session, this was also counted as the month of emergence.

Point following was coded with Mangold Interact 14. The infant’s reaction to the experimenters point was coded as ‘correct following’ when the infant looked in the direction of the correct object clearly beyond the experimenter’s index-finger. Trials were excluded when the infant did not attend the pointing gesture, or due to experimenter error (15 out of 668 Trials were excluded).The AoE of Point Following was defined as the infant correctly following the experimenter’s point in more than 50% of the valid trials in one session. Due to technical issues not all recorded sessions could be coded. Table 5-1 displays the included sessions for each measure.

Table 5-1. Sessions Included in Data Analysis

Measures	*n*						
	8m	9m	10m	11m	12m	13m	complete data sets
Decorated Room	30	29	29	28	28	26	22
Free Play	30	29	27	28	28	-	25
Point Following	26	26	26	26	28	25	16
Complete data sets incl. all three measures =16							

Coding for showing gestures during free play was also done using Mangold Interact 14 (analogous to Cameron-Faulkner et al., 2015). A showing gesture was coded if an infant held an object into the field of vision of their parents with the intention to direct their parents' attention towards the object. Parents could either take the object or not and the object could afterwards be placed/thrown by the infant into the proximity of their parents. The arm could be stretched or bent and afterwards the infant could also retract the object. Similarly to the decorated room procedure, the AoE for showing gestures was characterized as the use of at least two gestures during two successive months.

5.3.2 Reliability

A second trained coder, who was blind to the objective of the study, coded 10 of the videos. Reliability of scoring was determined by calculating Cohen's kappa. For the decorated room, the Kappa for parental points was .84 the Kappa for infant points was .82 (Kappa for infant index-finger points was .92 and Kappa for hand points was .79) and the Kappa for the decorated room overall was .83 all of which were substantial. Coding point following, the kappa for the category "following" was .84, which is substantial. The overall observed agreement for point following was .9. The overall kappa for showing gestures during Free Play was .82 which is also substantial.

5.3.3 Plan of Analyses

We broke down our analyses of the main longitudinal study into three main steps. As a first step, we assessed longitudinal change in each of our measures using repeated analyses of variance (ANOVAs) and paired t-tests for month-to-month comparisons to test for an age-related increase in behavior (one-sided). In addition, we tested for inter-individual stability of each behavior from month to month with Pearson Product-Moment Correlations (one-sided). As a second step, we tested whether our communicative measures would be synchronously interrelated as part of a common capacity emerging around 11-12 months, as expected from previous findings. Here, too, we used Pearson Product-Moment Correlations (one-sided).

In a third step, we addressed our main question regarding longitudinal predictors of index-finger pointing. First we tested for each behavior when it first emerged (at 8 or 9 months) whether it was longitudinally predictive of index-finger pointing using Pearson Product-Moment Correlations (one-sided). All correlation analyses were controlled using the Monte Carlo Permutation model and scatterplots were visually inspected for outliers.

For the predicted behavior, index-finger pointing, we used the variables AoE (ranging from 8-13 months); and the frequency of pointing at its median age of emergence. We also dichotomized the latter measure along its median to reduce variance in the frequency and obtain an age-centered measure for the presence/absence of pointing, and calculated phi-correlations. When predictors were interrelated in a given months, we applied partial correlations to identify the stronger association. Otherwise we determined the more meaningful predictors based on their longitudinal primacy. As an additional control for the longitudinal directedness of correlations, we tested whether significant predictors would themselves be longitudinally predicted by infant pointing. Finally, to complement our main analyses we ran multiple regression models with all identified predictors. Due to the within-subject design these multiple regression analyses included a smaller sample size. After the analyses of the main longitudinal study we report the results of the cross-sectional study that simply compared the mean frequency of parental pointing at 5 months and 7 months of infant age.

For all analyses that included more than one paradigm, we calculated mean amount of gestures per minute (corrected for visibility and length of recorded sessions). Preliminary analyses showed no effect of gender for infant behavior (all $p>.5$), thus data were collapsed across gender for further analyses.

5.3.4 Results

In the first section, we report on the longitudinal changes in parents' pointing, infants' pointing, infants' point following, and infants' showing gestures during the monthly assessments from 8 to 13 months of age. In the second section, test for synchronous interrelations at 11 months, to assess whether our measures reflect a common, newly emerged capacity for communication. In the third section, we analyze whether our measures predict longitudinally the age of emergence of index-finger pointing in the form of the age of emergence (see coding) and the more age-centered measure of pointing at 11 months which was the median age of onset of index-finger pointing (median split pointer yes/no, see the section on longitudinal development) and frequency at 11 months.

5.3.4.1 Longitudinal Development.

5.3.4.1.1 Pointing by infants and parents.

Figure 5-1 shows that infant pointing increased steadily over time $F_{(5,24)} = 18.22$. $p < .001$. Paired T-tests revealed significant month-to-month increases in pointing from 8-12 months (8 to 9 months: $t_{(25)} = 2.54$, $p = .017$;9 to 10 months: $t_{(28)} = 2.15$, $p = .040$; 10 to 11 months: $t_{(27)} = 2.86$, $p = .008$; 11 to 12 months: $t_{(27)} = 3.79$, $p = .001$; 12 to 13 months: $t_{(25)} = .92$, $p = .367$).

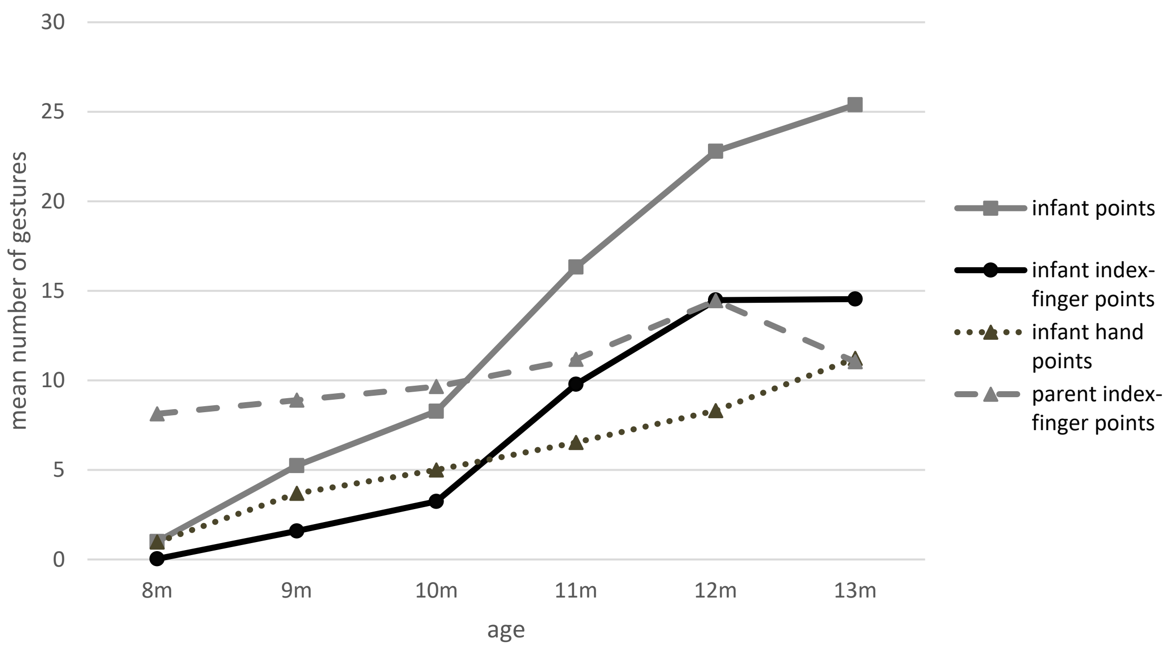

Figure 5-1. Longitudinal development of parental and infant pointing

Index-finger pointing increased significantly over time, $F_{(5,24)} = 11.82$, $p < .0010$, with steep significant increases from 10 to 11 months ($t_{(27)} = 2.81$, $p = .009$) and 11 to 12 months ($t_{(27)} = 3.17$. $p = .004$). Month-to-month correlations were high and significant from 10 months onwards (all $p < .015$, $r > .551$; see Table 5-3).

Table 5-2 displays the age of emergence (AoE) of index-finger pointing. At 8 months no infant qualified as index-finger pointer. 9 months was the earliest AoE for 6 infants. By 11 months more than half of the infants had achieved at least two index-finger points in two consecutive sessions (median AoE) and by 13 months 83,3 % of infants were classified as index-finger pointers. 5 infants did not use index-finger pointing reliably by 13 months.

Table 5-2. Age of Emergence of Index-finger Pointer and Whole-hand Pointer

Age (in months)	N (%) Index-finger Pointer	N (%) Whole-hand Pointer	Cumulative Percent Index-finger Pointer	Cumulative Percent Whole-hand Pointer
8	0	7 (23,3)	0	23,3
9	6 (20)	8 (26,7)	20.0	50
10	3 (10)	5 (16,7)	30.0	66,7
11	7 (23,3)	6 (20)	53.3	86,7
12	7 (23,3)	2 (6,7)	76.6	93,3
13	2 (6,7)	2 (6,7)	83.3	100
not achieved	5 (16,7)	--		

All infants used hand points during at least one of the sessions. At 8 months, 12 infants used hand points at least once during the session. Table 2 displays the AoE for hand pointing. The median AoE for being a hand pointer was 9 months. By 13 months all infants were hand pointers. The frequency of hand points increased over time ($F_{(5,24)}$ = 5.05, p =.008), but there were no significant month-to-month increases, only a significant difference between 8 and 13 months ($t_{(25)}$ = 3.92, p =.001). Infants continued using hand points together with index-finger points. Month-to-month correlations for hand pointing emerged relatively later than their first usage, from 10 months to 11 months and 12 months to 13 months (all r> .57; p<.001, ; see table 3), revealing that intraindividual stability of infants' hand pointing emerged after stability in index-finger pointing.

Parents' pointing remained mostly stable. All parents except for one pointed at least once during each session. Though a repeated measures Anova was significant ($F_{(5,24)}$ = 5.48, p = .002, $\eta_p 2$=21), paired T-Tests only revealed a significant increase of parental pointing from 11 to 12

($t_{(27)}$ = 2.99, p = .006) months, followed by a significant decrease from 12 to 13 months ($t_{(25)}$= 2.62, p = .015). A difference between 8 and 13 months was just significant ($t_{(25)}$ = 2.06, p = .049). Month-to-month correlations were high and significant across all time points (all r> .58, all p <.001; see table 5-3), revealing high intraindividual stability in parents' pointing for their infants.

Table 5-3. Month-by-Month Correlation Analysis of Infants' and Parents' Pointing

Age (in months)	8 to 9	9 to 10	10 to 11	11 to 12	12 to 13
N	29	28	27	27	25
Infant Pointing	.243	.414*	.553**	.848**	.611**
Infant Index-Finger Points	-.074	.299	.551**	.848**	.681**
Infant Hand Points	.282	.230	.604**	.573**	.152
Parents' Index-finger points	.700**	.669**	.739**	.811**	.832**

Note. **. Correlation is significant at the .01 level (1-tailed). *. Correlation is significant at the .05 level (1-tailed).

5.3.4.1.2 Point following.

Infants' point following skills increased over time ($F_{(5,24)}$ = 23.27, p < .001). Paired T-tests showed significant increases from 11 to 12 months ($t_{(23)}$ = 4.04, p < .001) and a significant difference between 8 and 13 months ($t_{(24)}$ = 5.36, p < .001). Month-to-month correlations emerged from 9 months onwards (all r>.39; p<.014, see table 5-4), revealing early emerging intraindividual stability in infants tendency to follow others' points.

Table 5-4. Month-by-Month Correlation Analysis of Point Following

Age (in months)	8 to 9	9 to 10	10 to 11	11 to 12	12 to 13
N	26	22	23	24	23
Infant Point Following	.051	.741**	.530**	.395*	.570**

Note. **. Correlation is significant at the .01 level (1-tailed). *. Correlation is significant at the .05 level (1-tailed).

Table 5-5 displays the AoE for point following. The earliest AoE for point following was 8 months (N=3). By 10 months more than half of the infants were classified as point-followers (median AoE).

Table 5-5. Age of Emergence of Point Follower

Age (in months)	Frequency	Percent	Cumulative Percent
8	3	12.5	12.5
9	8	33.3	45.8
10	3	12.5	58.8
11	3	12.5	70.8
12	6	25	95.8
13	1	4.2	100.00
not achieved	6	20	
Total	30	30	100

5.3.4.1.3 Showing gestures.

About a third of the sample (N= 9, 30%) already used showing gestures during the first session at 8 months. The number of showing gestures increased over time ($F_{(4,20)} = 8.77$, $p < .001$).

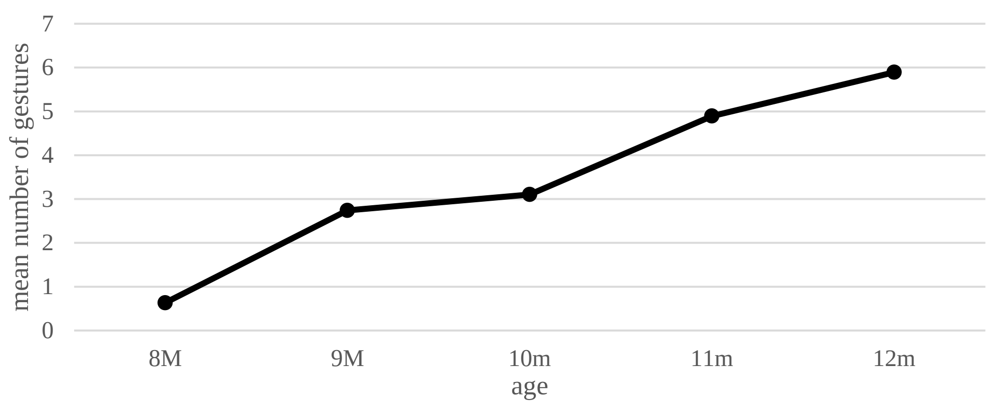

Figure 5-2 Longitudinal development of showing gestures

Paired T-Tests showed significant increase for showing gestures from 8 to 9 months ($t_{(29)}$= 4.4, $p < .001$) and 10 to 11 months ($t_{(25)} = 2.75$, $p = .005$), and there was a significant difference between 8 to 12 months ($t_{(25)}$= 6.16, p< .001). Month-to-month correlations were apparent from 8 to 9 ($r_{(28)}$=.52, p=.008) and 9 to 10 months ($r_{(28)}$=.39, p=.012) as well as 11 to 12 months ($r_{(26)}$=.58, p<.001), revealing individual stability in the use of the showing gesture from the beginning. Table 5-6 displays the AoE for showing gestures. By 9 months more than half of the infants used showing gestures (median AoE). Only two infants never used any showing gestures during any of the sessions.

Table 5-6. Age of Emergence of Showing Gestures

Age(in months)	Frequency	Percent	Cumulative Percent
8	6	19.4	19.4
9	10	32.3	51.7
10	5	16.1	67.8
11	4	12.9	80.6
12	4	12.9	93.5
not achieved	2	6.5	
Total	30	30	100

5.3.4.2 Synchronous Correlations.

In this set of analyses we tested whether at the median AoE of index-finger pointing (11 months), our communicative measures would be interrelated, perhaps as part of a common capacity. At 11 months, the frequency of infants' index-finger pointing and infants' point

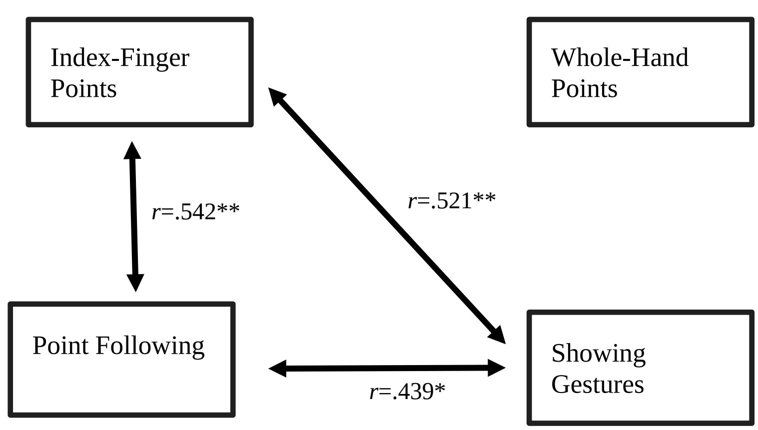

Figure 5-3. Concurrent correlations for infant behaviors at 11 months

Note. *<.05, **<.01

following abilities were highly correlated ($r_{(26)}$=.54, p=.002). This pattern held when relating median split groups (< median; => median) in a 2x2 contingency analysis ($\phi_{(26)}$=.63, p=.001). Further, index-finger pointing and showing gestures were highly correlated at 11 months ($r_{(28)}$=.52. p=.002), and the same pattern held for the median split groups ($\phi_{(28)}$=.43, p=.023). Point following at 11 months was further significantly related to infants' showing gestures ($r_{(26)}$=.44, p=.013) and the pattern was similar for the median split groups ($\phi_{(26)}$=.365, p=.074).Index-finger pointing and hand pointing were not interrelated (all r<.29, p> .07) suggesting that their usage is unrelated. Indeed, hand points were not correlated with any of the other measures (all r<.33, p>.096). Figure 5-3 illustrates that index-finger pointing, point-following, and showing gestures were all quite strongly synchronously interrelated at 11 months, while hand pointing was unrelated and appears to be a separate ability.

To reproduce an earlier finding by Liszkowski & Tomasello, (2011) we related parent pointing to infant index-finger pointing at 12 months. Results confirmed the previous finding showing a significant relation between parents' and infants' median split groups, $\phi_{(28)}$ =.358, p=.031. No further concurrent relations between infant and parent behaviors emerged.

5.3.4.3 Longitudinal Predictors of Index-Finger Pointing.

In the current set of analyses we looked for longitudinal predictors of the emergence of index-finger pointing. We tested for longitudinal predictors of the AoE of index-finger pointing. In addition we tested for predictors of the frequency of index-finger pointing at 11 months, which is the median age at which half of the infants pointed at least once with the index-finger. Further, we dichotomized our predictors and the outcome variable of index-finger pointing at 11 months along the median (2 index-finger points, however only one infant in the category actually used two points all other infants below the median did not use index-finger points) (> median vs. =< median) to control for large variances and allow for a clearer interpretation of related competencies. As predictors we used the earliest month available that provided sufficient variance. For parent pointing this was at 8 months, and for infant hand pointing, point-following, and show gestures, it was at 9 months.

5.3.4.3.1 Parental pointing as predictor.

Parental pointing at 8 months predicted the AoE of index-pointing ($r_{(25)}$=-.47, p= .009). The median split groups of parent pointing at 8 months also predicted the median split groups of infant index-finger pointing at 11 months ($\phi_{(25)}$ =.36, p=.028). The frequency of parent pointing at 8 months was not predictive of the frequency of index-finger pointing at 11 months ($r_{(25)}$=.14, p=.244).

5.3.4.3.2 Hand pointing as predictor.

Hand pointing at 9 months predicted the AoE of index-finger pointing ($r_{(25)}$=-.52, p=.001). Hand pointing at 9 months was also predictive of the frequency of index-finger pointing at 11 months, $r_{(27)}$= .48, p= .006. Similarly, the median split groups for hand pointing at 9 months and index-finger pointing at 11 months were related ($\phi_{(27)}$= .41, p=.034). A correlation between the AoE of hand pointing and the AoE of index-finger pointing failed to reach statistical significance ($r_{(25)}$= .27, p= .097).

5.3.4.3.3 Point following as predictor.

Point following at 9 months predicted the AoE of index-finger pointing ($r_{(22)}$=-.41, p=.03). Further, point following at 9 months predicted the frequency of index-finger pointing at 11 months ($r_{(25)}$=.5, p=.006). The same pattern emerged when correlating the median split groups of point following at 9 months and index-finger pointing at 11 months, $\phi_{(25)}$= .65, p<.001. The AoEs of point following and index-finger pointing were positively correlated ($r_{(22)}$=.62. p=.002).

5.3.4.3.4 Showing gestures as predictor.

Showing gestures at 9 months significantly predicted the AoE of index-finger pointing ($r_{(24)}$=-.41, p=.025). The same pattern emerged when correlating the median split groups of showing gestures at 9 months and median split of index-finger pointing at 11 months ($\phi_{(24)}$=.37, p=.022). Showing gestures at 9 months were also predictive of the frequency of index-finger pointing at 11 months ($r_{(27)}$=.34, p=.037). The AoE of showing gestures was correlated with the AoE of infants' index-finger pointing ($r_{(24)}$=.37. p=.037).

5.3.4.3.5 Control analyses.

In order to assure a direct relationship between the predictors of index-finger pointing and the AoE of index-finger pointing and its frequency at 11 months of age, we tested for any other correlations between the predictors at 9 months and later months. Should a correlation be significant and the predictors be significantly correlated with the AoE and/or the frequency of index-finger pointing at 11 months, we conducted partial correlations.

Showing gestures and hand pointing were significantly correlated at 9 months ($r_{(30)}$= .38, p= .044). When controlling for showing gestures, the partial correlation between hand pointing at 9 months and the AoE of index-finger pointing remained significant ($p_{\text{artial}(19)}$= -.37, p= .047). Similarly, when controlling for hand pointing at 9 months the correlation between showing gestures at 9 months and the AoE of index-finger pointing remained significant ($p_{\text{artial}(19)}$= -.44, p= .012). For the frequency of index-finger pointing at 11 months, a partial correlation with hand pointing controlling for showing gestures at 9 months remained significant ($p_{\text{artial}(24)}$=.42, p=.019). A partial correlation with showing gestures controlling for hand pointing at 9 months failed statistical significance ($p_{\text{artial}(24)}$=.22, p=.143).

Point following at 9 months correlated with showing gestures at 11 months ($r_{(25)}$=.59, p=.002). Since showing gestures at 11 months were also correlated with the frequency of index-finger points at 11 months a partial correlation analysis was conducted. Point following at 9 months

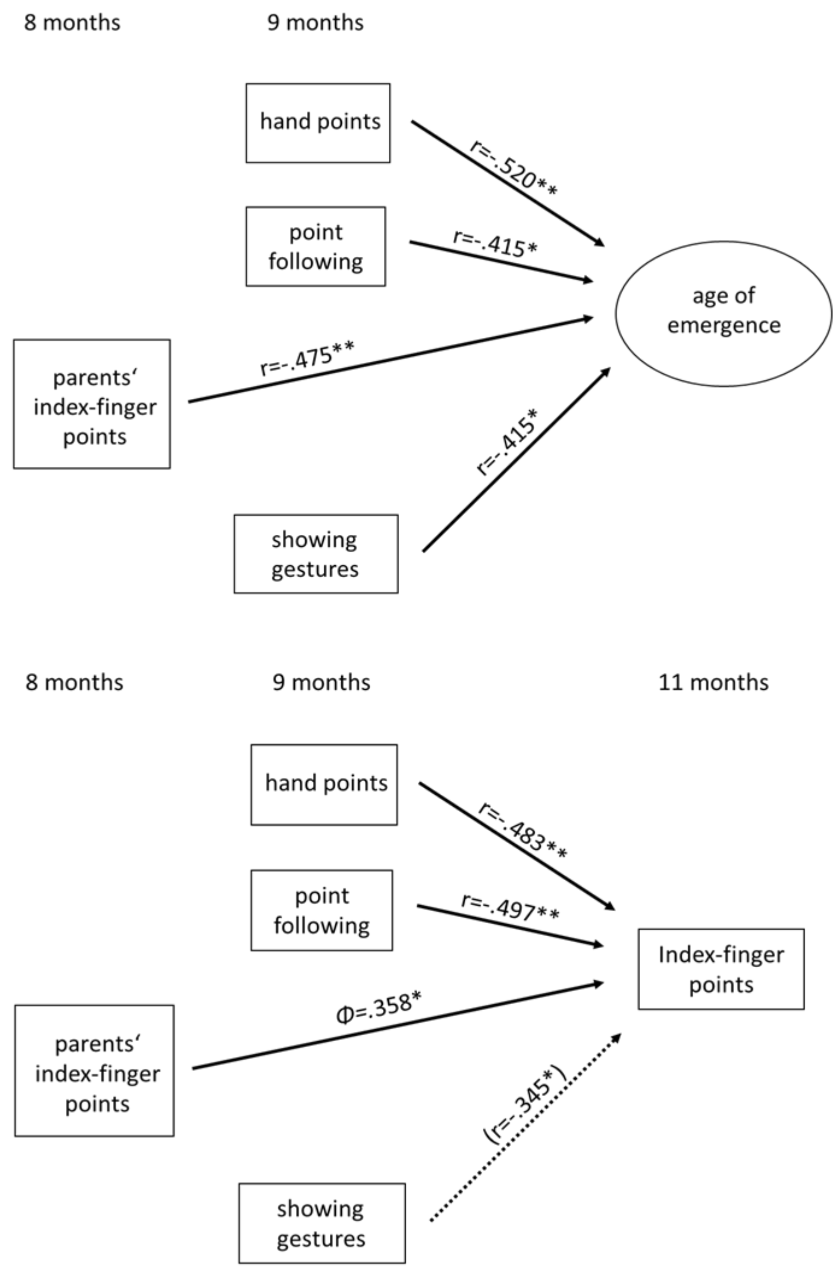

Figure 5-4. Longitudinal predictors of the age of emergence of index-finger pointing

Note. Upper panel: Predictions for the age of emergence of index-finger pointing (8-13 months); Lower panel: Prediction for the amount of index-finger pointing at 11 months. Pearson coefficients are first-order and set in () when partial correlation became insignificant. Phi-coefficients pertain to split-median groups. *<.05; **<.01.***<.001

remained a significant predictor of index-finger pointing when controlling for showing gestures at 11 months ($p_{artial(22)}$=.41, p=.047). None of the other predictors were significantly correlated with each other (all r<.33, all p>.114). Because parental pointing was the earliest predictor of index-finger pointing we also tested whether it had an early influence on the other communicative measures. Mean parental pointing at 8 months was not predictive of the onset or frequency of point following skills at 10 months or 11 months (all r<.32, all p >.114), and also not predictive of the onset of frequency or showing gestures at 9 or 10 months, all r<.22, all p>.242.

For each of our predicted significant longitudinal correlation we also checked for a reverse developmental directionality to counter arguments of false positives due to multiple testing and confine the scope of interpretation of developmental directionality. For example, when parent pointing predicted infant pointing at 11 months, we then tested whether infant pointing at 11 months would also predict parent pointing at 13 months. None of these correlations became significant, making our predicted correlations even more meaningful. Figure 5-4 shows a summary of all significant predictors of both the AoE of index-finger pointing as well as infants' ability to use the pointing gesture at 11 months.

5.3.4.4 Regression Analyses

In a final set of analyses we used our predictor variables to confirm the results in multiple linear regression analyses. Regarding the issue of multicollinearity, at 9 months the frequency of showing gestures and hand points were significantly correlated (r=.38, p=.044), however collinearity diagnostics revealed no VIF values above 3, making an influence of multicollinearity unlikely (Franke, 2010).

Predicting the AoE of index-finger pointing we entered all potential predictors (see Figure 4) at once: mean showing gestures at 9 months, mean proportion of point following at 9 months, mean hand points at 9 months and mean parental points at 8 months. As expected from the upper panel of Figure 4, we found a significant regression equation ($F_{(4,17)}$=7.16, p = .001), with an adjusted R^2 of .54, and parental points at 8 months emerged as a significant predictor, β=-.36, p=.043, as well as mean hand points at 9 months, β=-.52. p=.01.

As before, we split our predictor variables along the medians into dichotomous variables, to test in a binary logistic regression whether they would predict whether infants at 11 months did or did not use the index-finger pointing gesture. The binary logistic regression was significant, p= .043; Nagelkerke R^2 = .47). The model predicted 73.9% of cases (63.3% of non-pointers, 83.3% of pointers at 11 months). The only significant predictor was parental pointing at 8 months (Wald=3.97, df=1, p=.046). The odds ratio (OR) for parental pointing was .075 (95% *CI* .006 – .951).

To predict the mean frequency of index-finger pointing at 11 months we entered mean proportion of point following at 9 months, mean hand points at 9 months, mean showing gestures 9 months and mean parental points at 8 months. As expected from the lower panel of Figure 4, a significant regression equation was found ($F_{(4,20)}$=7.45, p = .001), with an adjusted R^2 of .52, and point following at 9 months emerged as predictor (β=.61, p=.001), as well as hand points at 9 months (β=.49. p=.006).

5.3.5 Discussion

The current study attempted to answer one main question, what predicts the ontogeny of index-finger pointing? We used a dense, longitudinal data set sampling parent-infant interaction and infants' use of communicative gestures in two different settings, while also assessing infants' point following abilities. More importantly we sampled interactional data before infants were known to start using the index-finger pointing gesture, contrary to other research on the ontogeny of index-finger pointing (Cameron-Faulkner et al., 2015; Kishimoto, 2017; Matthews et al., 2012).

Correlational analyses revealed several potential predictors of the age of emergence of index-finger pointing. The frequency of hand pointing at 9 months, infants' ability to follow a pointing gesture at 9 months as well as infants' frequency of using showing gestures during free play at 9 months were all significantly correlated with the AoE of index-finger pointing. Parental pointing frequency at 8 months was also a significant predictor. While hand pointing and showing gestures were correlated at 9 months both were still significantly correlated with the AoE of index-finger pointing after partial correlation analyses, none of the other predictors were interrelated. These results would support earlier findings by Matthews et al. (2012) on the importance of point following abilities for the onset of pointing as well as Cameron-Faulkner et al. (2015) who showed positive correlations between showing gestures and infant index-finger pointing.

However, the results of the regression analyses revealed parental pointing at 8 months to be a particularly strong predictor of the AoE of index-finger pointing and neither point following nor showing gestures remained as significant predictors, only hand pointing at 9 months also remained significant. And the results of the binary logistic regression analyses predicting whether infants were index-finger pointer at 11 months also supported the unique importance of early parental pointing.

Yet, when predicting the actual frequency of index-finger pointing at 11 months while correlation analyses also showed hand pointing and parental pointing as well as point following to be significant predictors, only point following and hand pointing remained as significant predictors.

These results speak to a combination model, with early social shaping (Delgado et al., 2009; Masataka, 2003) by parents as an important predictor of the onset of index-finger pointing and infants' own referential abilities using deictic gestures like hand pointing and being able to follow a pointing gesture as important cognitive indicators of competence and onset (Butterworth, 2003; Cochet & Vauclair, 2010; Leroy et al., 2009; Leung & Rheingold, 1981; Liszkowski & Tomasello, 2011; Matthews et al., 2012).

Concurrent correlation analyses were able to show that once all abilities have emerged, point following, index-finger pointing and showing gestures seem to be part of one common capacity of communication, while whole-hand pointing is unrelated and possibly a different ability which confirms results on the link between index-finger pointing and language (Lüke et al., 2017; Lüke, Grimminger, Rohlfing, Liszkowski, & Ritterfeld, 2016).

When and why do parents actually start pointing for their infants? In the current sample, parents' pointing did not significantly increase and most parents already pointed when their infants were 8 months old.

5.4 Study 2

Since parental pointing was mostly stable in Study 1, we wanted to explore earlier parental behaviors in a second study observing 6 and 8 months old infants and their parents in the decorated room.

5.4.1 Method

44 infants and their parents from Hamburg who were recruited from a database of caregivers that had previously agreed to participate in infant studies. 1 dyad was excluded from the statistics because the parent had allowed the child to touch all the objects in the room thus

impeding communication through pointing. This left 20 children between the ages of 5.5 – 6.5 months (mean age = 183.5 days, range = 169 – 195 days; 11 girls) and 23 between 8.5 – 9.5 months (mean age = 270.65 days, range = 258 – 283 days; 11 girls). In most cases (39 of 43 participants, 91%) the infants were accompanied by their mothers. Parents were on average 34.72 years old (*SD* = 3.51).

5.4.1.1 Procedure.

In order to replicate a social interactional we again used the decorated room setting and procedure also used in study 1.

5.4.1.2 Coding.

Coding was done using Interact 14, a software for qualitative and quantitative analyses of video data. Pointing was coded no matter whether the arm was fully extended or not. Also the rotation of the hand did not matter. If the arm was stretched out further during a point it was still coded as the same pointing gesture unless the gesture included two clearly different objects. Two different types of pointing were coded. The first class of pointing comprised the index-finger pointing which meant that the index-finger was outstretched relative to the other fingers. The second pointing class included pointing with the whole-hand or other hand-formations. If the differentiation between these two categories was not possible because the hand of the caregiver was not caught on video it was coded as an unclear pointing gesture.

Any manipulations with the exposed objects were not reported. Besides the gestures and movements executed by the children were not coded since at the age of the participating children a deliberate pointing gesture could not be expected.

5.4.1.3 Reliability.

Reliability was obtained through a re-coding of 20% of the video material. Kappa was calculated over all pointing gestures (index-finger pointing, whole-hand pointing, pointing and touching and unclear pointing). The overall Kappa coefficient was k = .86 indicating a very good reliability.

5.4.2 Results

Looking at the age groups separately parents of older children were expected to point more often for their infant than the parents of the younger ones. Within the group of the 5 – 6 months old infants, the parents pointed on average M = 3.05 (SD = 4.5) times. 10 out of 20 (50%) did utilize a pointing gesture at least once. Because of the high proportion of parents that did not point at all the skewness of the distribution of index-finger pointing in the younger age group was z = 2.88 which was significant at a p = .01 level. Consequently non-parametric tests were used. The mean amount of pointing for parents of the 8 – 9 months olds was M = 5.13 (SD = 4.22). 19 of the 23 parents (83%) pointed at least once for their child. A Mann-Whitney test revealed a significant difference in the amount of parental pointing between these age groups ($U(20,23)$ = 149.5, z = -2.00, p = .02). Since a considerable amount of parents never pointed at all parents were split into those who pointed at least once and those who never pointed. Parents of older children were more likely to point for their children (φ=.37, p=.014). No infant index-finger points were perceived during any session.

5.4.3 Discussion

Study 2 was able to show that parents of younger infants (5-6 months) used less pointing gestures overall and were less likely to point for their infants. Only half of the parents actually used pointing gestures at 5-6 months. However, we were not able to find the age where no parents point for their infants. It is possible that some parents who would not point for their infants during natural interactions actually used pointing gestures in the decorated room since without being able to touch the objects, and no other activities present, there are not many activities available for them. The results are in line with previous research by Gogate, Bahrick and Watson (2000) who studied parental input (gestural and lexical) during a novel word learning task and subsequent semi-structured play sessions. Mothers tended to point to static objects more frequently if the child was between 9 – 17 months than for younger children between 5 – 8 months or older ones at the ages of 21 – 30 months. They equated this to infants' ability to comprehend word-label combinations. Future studies should also include measuring parental pointing in other environments, for example during free play and at home.

5.5 General Discussion

Overall, the results speak to a combination model, with early social shaping (Delgado et al., 2009; Masataka, 2003) by parents as an important predictor of the onset of index-finger pointing and infants' own referential abilities using deictic gestures like hand pointing and being able to follow a pointing gesture as important cognitive indicators of competence and onset (Butterworth, 2003; Cochet & Vauclair, 2010; Leroy et al., 2009; Leung & Rheingold, 1981; Liszkowski & Tomasello, 2011; Matthews et al., 2012).

Some important questions remain. What actually makes parents start to point for their infants since they themselves only start pointing a couple of months later (see Study 1)? Potentially parents start sensing a growing attentional capacity in their infants which prompt them to start pointing for their infants. Parents appear to be quite competent at judging their own child's abilities (Voß, 1994) and show a certain sensitivity to anticipated development (Matthews et al., 2012; Tamis-LeMonda, Chen, & Bornstein, 1998). The way parents perceive their child has an effect on their behaviors towards the infant (S. A. Miller, 1988). Parental pointing is most likely not a modeling behavior but a response to developmentally earlier infant behaviors. There might be some kind of individual cognitive attentional component, maybe children detach from objects and begin to explore the environment and this in turn is answered by parents through increased attention direction behaviors, which leads to increased skills in point following and to infant pointing.

The fact that point following is not predicted by parental pointing also adds evidence to that hypothesis meaning parents' pointing is most likely a response to infants' ability to follow their attentional focus. Other researchers have pointed to the importance of parental sensitivity to their infants' attempts at communication (Ger et al., 2018; Kishimoto et al., 2007; Liszkowski & Tomasello, 2011) with contingency and/or referential uptake as important factors. If modeling is not important other deictic gestures by parents like showing gestures could also be predictors of index-finger pointing. The earlier ability of showing gestures and its correlational relation to the onset of index-finger pointing as well as the strong correlations between whole-hand pointing and index-finger pointing imply that infants already have referential goals when using deictic gestures before they are able to use the index-finger gesture. It might be important to start even earlier when trying to pinpoint the exact predictors of the onset of infant pointing as well as potential predictors of infants' ability to use the hand pointing gesture and showing gesture.

One limitation of the studies presented here is that we assessed parental pointing only in the decorated room which is a paradigm that has been shown to elicit pointing behavior (Puccini et al., 2010) and might not reflect parent-infant interaction in their everyday environments (Salomo & Liszkowski, 2013). However, since parents were not instructed to show any specific behaviors, and similar "contexts of regard" do also appear in their everyday environments, parents' reactions to their infants' communication should reflect the interactions at home. However, sampling parent-infant interaction in their natural environments would be important to cement the results collected here. All of the presented exploratory analyses should further be confirmed by training studies increasing parental pointing and/or contingent reactions before infants themselves begin to point.

The current study adds important evidence to the understanding of the ontogeny of index-finger pointing. From an applied perspective these results add evidence on the potential importance of early intervention.

6. SOCIAL INTERACTIONAL PREDICTORS OF INFANT PREVERBAL GESTURES AND VOCABULARY

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6.1 Abstract

Despite its importance to infant development, little is known about the ontogeny of index-finger pointing. We report on the results of a longitudinal study with 46 parent-infant dyads from a diverse sample of German families and German-Turkish families. Data collection took place monthly from when infants were 8 months old until they were 14 months old with additional testing when they were 18 and 26 months old. Parent and infant deictic gesture use was assessed using a variety of interactional settings, from naturalistic home observations to semi-structured observations in the laboratory, as well as infants' language development. We compared gesture use across settings, finding significant differences in the patterns of gesture use for parents but not infants. Overall, the decorated room proved to be superior at capturing the onset of infant index-finger pointing. The free play procedure was shown not to be a suitable setting to measure infant and caregiver point production. Both caregiver pointing at home as well as in the decorated room was predictive of the age of emergence (AoE) of infant index-finger pointing. In addition, caregiver referential uptake of infants' early whole-hand pointing gestures as well as caregiver deictic gestures aimed at objects infants were focusing on were also predictors. The AoE of index-finger pointing was a significant predictor of language development at both 18 and 26 months. Parental pointing at home was also a significant predictor of later language abilities, even when controlling for its relation with the AoE of index-finger pointing. The results point to important methodological concerns when studying caregiver-infant interaction. Further, they underline the influence of social-interactional experiences on the ontogeny of index-finger pointing during infants' first year of life.

6.2 Introduction

Humans are exceptionally gifted at communication, both verbally and non-verbally. Starting at about two months of age infants begin to communicate using smiles and vocalizations (Renzi, Romberg, Bolger, & Newman, 2017). Over the course of the next two years, these early communication attempts develop, first into gestural communication, and then into language. From the very beginning, parents react to their infants' communicative attempts and model different behaviors for their infants', socializing communicative abilities. However, does socialization influence the onset of deictic gestures? Moreover, what is the relationship between parental and infantile deictic gestures and infants' emerging language abilities? Further, are traditional, economic ways of recording interaction in the laboratory adequate representations of caregiver-infant interaction, or is it important to observe their interaction at home? We are considering two main milestones, the onset of index-finger pointing and the development of language. Does the socio-cultural environment in the form of caregiver input influence the development of these two important communicative abilities? We record and compare caregiver input from a diverse sample of Turkish-German and German families in the laboratory and at home.

Index-finger pointing has already been shown to be particularly important among deictic gestures. It is a gesture that is used in a unique way by humans compared to all other species (Liszkowski et al., 2009; Tomasello, 2005) and its abnormal development is indicative of autism spectrum disorders (Baron-Cohen, 1989b) and language delay (Lüke et al., 2016; Lüke et al., 2017). While very little is known about the influence of socialization on the ontogeny of index-finger pointing, we do know it is a gesture that is universal to humans (Liszkowski et al., 2012; Veena & Bellur, 2014). However, both onset and frequency of pointing vary across cultures

(Callaghan et al., 2011; Liszkowski et al., 2012), and other forms of pointing exist such as lip-pointing (Enfield, 2001), making an influence of socialization probable.

Regarding the onset of pointing, infants usually start to point with the index-finger around their first birthday (Bates et al., 1975; Butterworth & Morissette, 1996; Colonnesi et al., 2010; Iverson & Goldin-Meadow, 2005). Before that, they already use other deictic gestures like reaching for an object (Murphy, 1978) showing/giving an object (Bates et al., 1975; Cameron-Faulkner et al., 2015) and using the whole-hand to point at objects (around 8-10 months, Lock et al., 1990, Rüther & Liszkowski, submitted). They also use vocalizations which already have some communicative intent (around 7-11 months Esteve-Gibert & Prieto, 2013). All of these behaviors indicate that index-finger pointing does not emerge spontaneously, but is based on earlier social-communicative abilities.

There are several potential pathways for the influence of caregiver pointing. First, infant pointing might result from imitating their parents gestures (Lock et al., 1990). Second, infants' own attempts at pointing, either non-communicatively (Carpendale & Carpendale, 2010; Delgado et al., 2009), or using other earlier forms of pointing like whole-hand pointing, or even other deictic gestures like reaching might be shaped through parental reactions into index-finger pointing (Cameron-Faulkner et al., 2015; Murphy, 1978).

As far as the influence of caregiver modeling goes, most of the evidence is based on concurrent correlations between caregiver and infant pointing found at 12 months (Liszkowski & Tomasello, 2011) and at 14 months (Rowe & Goldin-Meadow, 2009a) as well as a cross-cultural study with dyads from different cultural communities between 10 and 14 months (Liszkowski et al., 2012). A more interesting finding by Salomo & Liszkowski (2013) showed that age-matched infants from three different cultural groups (Shanghai-China, Yucatan Mexico and the

Netherlands) had different ages of onset of infant pointing in accordance with their cultural group as well as different frequencies of caregiver pointing and deictic gesture use, implying a potential influence of caregiver pointing on the onset of infant pointing. One important longitudinal finding from Rüther & Liszkowski (submitted) showed that a higher frequency of caregivers' points at 8 months correlated with age of emergence (AoE) of index-finger pointing, where infants whose caregivers displayed a higher frequency of pointing gestures at 8 months demonstrated an earlier AoE of index-finger pointing. Results from a second study in that same publication showed~~,~~ that caregivers of 8 months olds were more likely to point for their infants than parents of 6 month olds, suggesting that caregiver pointing is rather a reaction to infants' emerging skills than simply a modelling behavior.

Two training studies on the influence of caregiver pointing revealed somewhat conflicting results. Marcos (1991) instructed parents of 12-13 month-old infants to either engage as much as possible in referential exchanges with their infants about a poster while the other group was free to interact in any way they liked resulting in higher pointing frequencies of infants within the experimental group in a subsequent test session. However, since infants were tested at 12 and 13 months most of them were already able to point. Matthews et al. (2012) used a training study design to examine the influence of parental pointing on the AoE of index-finger pointing. They instructed parents of 9-11 month olds to point for their infants at home during a one month period. The authors did not find an increase in the frequency of infants' index-finger pointing in the experimental group but found a small difference in the AoE of index-finger pointing according to infants' performance in a gaze checking task which in turn was affected by training, leading the authors to suggest that gaze-following, not index-finger pointing is socialized by parental pointing. However, the authors did find a correlation between parents' pointing during free play and infants' pointing in a different experimental situation weeks later, suggesting a more situation-general relation between parent and infant pointing? Potentially referential uptake, either through pointing gestures, vocalizations or other deictic gestures is responsible for the onset of index-finger pointing in infants.

There have been some promising results regarding the influence of caregiver uptake of infants' gestures. Miller and Lossia (2013) found a significant correlation between caregivers' temporally contingent responses to infants' gestures and the frequency of infants' gesture use. Kishimoto (2017), using a longitudinal design, was able to show that the proportion of caregivers' temporally contingent responsive points predicted an increase in frequency of infant pointing during later months. Similarly, Ger, Altinok, Liszkowski and Küntay (2018) expanded on this finding by showing that especially those contingent reactions that included a referential uptake of the infants' earlier pointing gesture (including moving towards the object and naming the object) at 10 months predicted an increase in frequency at 12 months. The relevance of caregiver responses seems to be of particular importance. Research has shown that 12 months old infants already expect a referential response to their pointing gestures (Liszkowski et al., 2004). However, since both studies were conducted using the decorated room paradigm and assessed infant and parent pointing at the same time, this meant infants already had to be able to use a pointing gesture (even if those could be whole-hand points) to receive a response. While these results are highly promising, sampling parent-infant interaction in different settings, not just point elicitation paradigms might further elucidate the connection between referential uptake and infant pointing.

The connection between gesture and language, and index-finger pointing and language in particular, is well established. Index-finger pointing has been shown many times to be particularly important for language development (Butterworth & Morissette, 1996; Capone & McGregor, 2004; Cochet & Byrne, 2016; Colonnesi et al., 2010; Iverson et al., 1994; Iverson & Goldin-Meadow, 2005; Mumford & Kita, 2016; Murillo & Belinchón, 2012; Rowe & Goldin-Meadow, 2009b; Sauer et al., 2010). The results of a meta-analysis by Colonnesi et al. (2010) showed that this relation is also true across different experimental and cultural settings (USA, Italy, England, Spain & Japan). Lüke et al. (2017) were able to show that infants who still used whole-hand points instead of index-finger points at 12 months were more likely to qualify as language delayed at 24 months. Rowe & Goldin-Meadow (2009b) showed that the amount of items referred to by gesture at 18 months predicted infants' vocabulary at 42 months and the number of gestures and object-directed vocalizations predicted later syntactic complexity. The onset of index-finger pointing also correlated with later language comprehension at 14 months (Butterworth & Morissette, 1996) and 24 months (Desrochers, Morissette, & Ricard, 1995). It could be that infants learn that their gestures are usually responded to by their caregivers, and thus increase gesturing to increase speech acts by parents and opportunities for learning. It has been observed, that when infants point, caregivers will typically comment on the referent (Kishimoto et al., 2007; Marcos, 1991).

Parental gestures accompanying their speech acts are also strong predictors of later vocabulary size (Pan et al., 2005; Talbott, Nelson, & Tager-Flusberg, 2015; Tamis-LeMonda et al., 2014). One simple explanation might be that parents' and infants' gestures correlate and the latter actually predicts language ability (Rowe et al., 2008). However, parental gestures might lead to increases in joint attention episodes and lead to more sustained attention during those joint attention episodes, helping infants with word-meaning mapping (Morales et al., 2000; Wass et al., 2018; Yu et al., 2019; Yu & Smith, 2016). Yu and Smith (2016) presented evidence that sustained attention episodes were more frequent when parents attended an object infants were focusing on, and that sustained attention in particular was predictive of later vocabulary size.

Considering the importance of index-finger pointing for language development as well as the interrelatedness of parental input, language and infant gesture, disentangling their developmental relationships is critical.

On a methodological level, several further things need to be considered when studying parent-infant interaction. Developmental research with infants is mostly conducted on so-called WEIRD (Western, Educated, Industrialized, Rich and Democratic) convenience samples, which may lead to very similar social-interactional environments for infants (Nielsen & Haun, 2016; Nielsen, Haun, Kärtner, & Legare, 2017b). Measures of parent-infant interaction are also most often taken using so-called “free-play” procedures, often in the laboratory for convenience, where a set of toys is provided or sometimes administered at home. These settings usually use minimal instructions and mothers are asked to conduct themselves as they normally would. The expectation is that this would allow for the observation of naturally occurring behaviors of the caregiver and infant. A high amount of ecological validity is assumed. However, recent cross-cultural research has shown that the behavior of parents and infants is influenced by situational factors, and behavior in standardized laboratory settings might not correspond to naturally displayed behavior (Ahnert & Haßelbeck, 2014; Lamm et al., 2014; Puccini et al., 2010). While there has not been an extensive study of these potential differences, there have been differing results with some studies reporting slight or no differences between the two settings (Bornstein, Haynes, Legler, O'Reilly, & Painter, 1997; Kniskern et al., 1983), and with other studies showing an increase in behavior that is deemed to be socially desirable (Belsky, 1980; Lamm et al., 2014). Other influencing factors were found to be the length of the assessment (Leyendecker, Lamb, & Schölmerich, 1997), and the interactional context (Puccini et al., 2010). Puccini et al. 2010 used two different interactional contexts, with the free play procedure focusing on object exploration and the decorated room procedure focusing on observing objects, where they recorded differences in language use as well as in types and counts of deictic gestures.

Especially research on the onset and development of pointing often employs a different experimental setting to assess infant pointing, i.e. free play procedures, which comprise of puppet shows meant to elicit pointing, sometimes including instructions to the parents (Colonnesi et al., 2010). Which setting is the most effective to measure the onset of infant index-finger pointing? While, we would expect infants to first show index-finger pointing in the decorated room, it might be, however, that the familiar environment of their home with the naturally occurring behavior between caregiver and infant might elicit earlier instances of pointing. The decorated room procedure, being semi-standardized and taking only five minutes of observation time would be a much more economical way of assessing infants' competence as well as caregiver gestural input, compared to longer, less structured observations at home, in infants' natural environments.

To account for these potential differences, we included three different types of measures: a free play procedure and the decorated room in the laboratory as well as naturalistic observations at home over longer periods of time, in the current study.

Further, we included a more varied sample that should also be more representative of infants' environments in Germany by including families with a Turkish migration background, a largely understudied part of the population in Germany (Durgel, Leyendecker, Yagmurlu, & Harwood, 2009). Turkish migrants arrived after a large wave of planned migration due to a lack of qualified workers in Germany during the 1960s and an extension of their stay allowed their families to relocate to Germany in the 1970s (Butterwegge, 2005). This makes them the biggest migrant group living overall in Germany as well as in Hamburg (Statistisches Amt für Hamburg und Schleswig-Holstein, 2018). Migrants are a highly underrepresented sample in research and present a very interesting case for comparison since many parameters concerning the infants' social cultural environment are similar, like institutions concerning childcare but cultural values concerning childcare and language tend to be different (Daglar, Melhuish, & Barnes, 2011; Döge & Keller, 2013; Lavelli, Döge, & Bighin, 2015; Salomo & Liszkowski, 2013).

The current study attempts to answer several questions. First, how are infant and parent deictic gestures and their interactions distributed across different settings, i.e. at home during natural observations, in the laboratory during free play and in the decorated room? We expect the decorated room to be uniquely suited to capturing the onset of infant pointing, with fewer and later pointing events during free play and at home. We also expect at least some difference in behavior from parents in the laboratory compared to the home environment.

Second, the earlier study from Rüther & Liszkowski (2019) revealed predictors of pointing both on the child level (showing, point following, hand pointing) and the caregiver level (pointing). It also suggested that caregiver pointing is rather a reaction to infants' emerging skills, than just a modeling behavior, since parents of 6-month-olds pointed less than parents of 8-month-olds. We expect to replicate these earlier findings. If the lab based assessment is a valid indicator of naturally occurring differences at home (Salomo & Liszkowski, 2013), we should also find the same predictors in the home setting. If other parental behaviors (i.e. showing gestures) as well as an even more general measure of triadic interaction were significant predictors that would indicate even further that infant pointing is not simply mimicking parent behaviors. Similarly, are parental responses to infant behaviors (especially gestures aimed at objects infants are focusing on (Yu et al., 2019) as well as referential uptake of infants' pointing gestures (Ger et al., 2018)) predictors of infant index-finger pointing?

Third, can we replicate findings on the influence of infant index-finger pointing on language development? If parental input and infant index-finger pointing as predictors of language are related across infant development, we should find similar predictors for both the age of emergence of index-finger pointing and language. If index-finger pointing is central to language development, these predictors should no longer be significant when controlling for index-finger pointing.

6.3 Methods

The current study was part of a larger international project on the socio-cultural and cognitive development of infants during the first two years of life. Data collection took place in Hamburg, funded by the BMBF (Bundesministerium für Forschung und Bildung) and at the Koç University in Istanbul, Turkey, funded by the Tübitak (Turkish Science and Research Agency).

6.3.1 Sample

The sample in Hamburg consisted of 47 parent-infant dyads made up of families with Turkish migration backgrounds (*N*=14, male=8, female=6) and families without migration background (*N*=32, male=17, female=15). SES was kept mostly constant (see table 6-1 and 6.2). Families were recruited using a database of families who had given prior consent to be contacted regarding participation in scientific studies. However, since there were very few families with Turkish migration background in the database, recruitment was extended by visiting kindergartens, neighborhood fairs and festivals, canvassing neighborhoods, and contacting childcare and education facilities (Elternschulen etc.), a Facebook campaign, as well as canvassing about the study in Turkish supermarkets, grocery stores etc.

Table 6-1. Mean age, income and number of children for Turkish German and German families

	culture	N	M	SD	Range
Age (primary caregiver)	Turkish	14	35.62	4.62	28-42
	German	32	35.42	3.78	29-43
Age (secondary caregiver)	Turkish	3*[1]	31.33	3.21	29-35
	German	19*[1]	35.94	6.07	28-54
Household Income	Turkish	12*[2]	3458.33	1581.71	1500-7000
	German	30*[2]	4248.33	1813.28	1600-11000
No. of children	Turkish	14	2.15	1.28	1-5
	German	32	1.48	.71	1-3

Note. *[1] the question was only added for the second wave of data collection thus information is missing on N=11 Turkish-German and N=13 German families *[2] N=2 German and N=2 Turkish-German families refused to give information on their income

Though Turkish-German and German families were planned to be matched on SES there was a significant difference in the education of the primary caregiver with Turkish German families having a slightly lower amount of formal education ($\varphi(45)=.417$, $p=.005$) (see table 6-2) and a significantly higher number of children on average ($t(45)=2.55$, $p=.015$). They were matched on income and age (for income $t(41)=-7.41$, $p=.465$, for age $t(44)=.145$, $p=.896$) (see table 6-1).

Table 6-2. Amount of formal education of German and Turkish-German primary caregivers

		Degree						
Culture	Caregiver	University Master or higher		University Bachelor or equivalent		School diploma or equivalent		missing
		N	%	*N*	%	*N*	%	*N*
German	1st	17	53	12	37	3	10	
	2nd	18	56	10	34	3	10	
Turkish-German	1st	2	14	6	43	6	43	
	2nd	4	29	4	29	4	29	2

Among the group of families with a Turkish migration background, four of the primary caregivers were first generation migrants, meaning they were born in Turkey and 10 were second generation migrants meaning their parents were born in Turkey. Of the secondary caregivers 8 were first generation migrants and six were second generation migrants. For four families both parents were first generation migrants. For the group with a German cultural background all parents were born in Germany, as were their parents. Of the 14 families with a Turkish cultural background, 7 families reported to raise their child bilingually using both German and Turkish at home and 7 families reported to only speak Turkish with their child.

6.3.2 Procedure

Before participating, parents signed letters of informed consent. After every session, a small gift was given as a token of gratitude. Upon completion of all sessions, parents received a booklet that included a short description of all of the measures included in the study, an edited version of the video recordings as well as pictures of the sessions and an honorary certificate for the infant.

Families visited the laboratory for standardized testing sessions including behavioral and cognitive measures as well as unstructured free play sessions, monthly from 8 to 14 months and later at 18 months. 24 of the monolingual German families also returned to the laboratory when infants were 26-28 months old to participate in a separate study on the development of theory of mind. The families were also visited at home three times during the course of the study, at 8 months, 10 months and 18 months and observed for one hour. All sessions were recorded on video. Four families did not complete testing, three families dropped out at 12 months and one family dropped out at 11 months. 39 families attended the last laboratory session at 18 months. Two appointments at 18 months had to be cancelled due to illness of the infant. One infant was removed from data analysis after testing (and dropped out when the infant was 11 months old) because of illness. 28 families attended every session. At the beginning of the study, parents were asked to name the primary caregiver who would attend all laboratory sessions in order to keep our account of parental input as reliable as possible, and in four cases, this was the father; in all other cases, it was the mother. However in some cases (*N*=10), due to illness or changes in their professional situations, the primary caregiver attending the laboratory sessions changed. Since this was still a representation of the primary input infants received we included these cases in all analyses.

Data was collected +/- 7 days around infants' monthly age. Attendance at each time point can be found in table 6-3.

Table 6-3. Attendance for all measures 8-26 months

measure	Age in months								
	8	9	10	11	12	13	14	18	26-28
Home-visit	45 (0/1)*	-	41 (3/2)	-	-		-	40 (5/1)	
FRAKIS/TIGE II	-	-	-	-	-			36	
Decorated Room	46	45 (0/1)	41 (5/0)	39 (5/2)	42 (4/0)	37	39		
Free Play	46	46	41 (5/0)	41 (5/0)	42 (4/0)				
SG/SCS	35								
SES	45								
SETK-2									24 (22/0)

*Note:**(session not attended/recording error)

6.3.3 Measures

The current study includes behavioral data from the decorated room, free play sessions, home observations (both analyzing video recordings as well as live coding interaction formats) as well as questionnaires on infants' vocabulary, families' SES, socialization goals and cultural self-construal.

Tasks were always presented in a fixed order rather than counterbalancing across infants. This was done to even out the possible order and fatigue effects and is standard practice in research on individual differences (Carlson & Moses, 2001). Infants and their parents first entered the decorated room in order to assess the development of infants' and parents' pointing. The decorated room (Puccini et al., 2010) is designed analogous to a museum exhibit including 20 interesting objects hung on the walls. Parents are asked to look at the objects together with their infant without either of them touching any of the objects and were otherwise blind to the purpose of the study. Afterwards different behavioral and eye tracking tasks were administered, which are not part of this analysis. At the end of each session parents were asked to interact with their infants using a provided set of toys without any other instructions (Bakeman & Adamson, 1984). They were asked to stay on a blanket that was laid out in the middle of the room and behave as if they were at home with their infant. Sessions were recorded by four 360° cameras in each corner of the room. Both the decorated room and the free play session lasted five minutes each.

The families were visited at home three times when infants were 8, 10, and 18 months old, within one week of the laboratory sessions. Prior to observation, caregivers were informed that the everyday activities of their infants were of interest in this study. Therefore, caregivers were asked to behave in a natural way and to pursue activities during observation as usual. The technical set-up allowed for free movement even outside of the home. Each observation session lasted approximately one hour.

Each child was assigned to one of two trained researchers of the institute, so that a child was observed by the same researcher in all sessions. Both observer and infant were equipped with a head-mounted camera filming the sessions. The infant head-camera was removed by the observer during observation, when it distracted the infant. Since the amount of data and quality of data from the infant-head camera was extremely varied, and missing for many of the infants due to their refusal to wear the camera, it was not included in this analysis. In order to reduce reactivity effects (Lipinski & Nelson, 1974) the observer tried to keep a certain distance to the subjects which allowed both adequate observation and filming, while being as little intrusive as possible. Furthermore, the observer avoided to initiate interactions, but reacted appropriately, when addressed by one of the subjects, to maintain a natural and unforced atmosphere.

One hour of unstructured interaction was recorded using a small sports camera (Panasonic HX-A500, 12,76 Megapixel, frame-rate 1.920 x 1.080/25p, wide-angle recording format), attached to the experimenters head. The observer conducted a direct scan sampling of infant's engagement state (based on Bakeman & Adamson, 1984) using the Obansys App (Mangold International GmbH) on a tablet device.

Infants' language abilities were assessed at 18 months (only the productive vocabulary was assessed) using the FRAKIS ("Fragebogen zur frühkindlichen Sprachentwicklung" (Szagun, Stumper, & Schramm, 2014) and TIGE II (Acarlar et al., 2009). German monolingual families only received the FRAKIS. Turkish monolingual families only received the TIGE II and bilingual families were asked to fill out both questionnaires.

Around 26 months of age, language was assessed again for a subset of the German monolingual infants using the widely used language test for 2-year-old children, SETK-2 ("Sprachentwicklungstest für zweijährige Kinder",Grimm, 2000) for German speaking children, a standardized and norm-referenced instrument. The SETK-2 includes two subscales measuring language comprehension (words/sentences) and production (naming objects/scenes in pictures) and a test for sentence production (explaining pictures). For the bilingual children, in order to determine a vocabulary score, we calculated the amount of words understood/spoken irrespective of language using the so-called "translation equivalents" (Junker & Stockman, 2002) so as to not inflate the count. In other words, if the infant understood/spoke a word in both languages, it was counted only once. Due to the high variance of vocabulary size at 14 and 18 months, log frequencies were used for predictive analyses and group level differences.

Cultural self-construal (SCS, (Singelis, 1994)) and socialization goals (SGQ, (Kärtner et al., 2007)) were measured during the 10 months session. Both questionnaires measure independent/interdependent cultural values in the form of parents' own values in the case of the SCS, and, in the case of the SGQ, parents were asked about traits they wanted their children to achieve by 3 years of age. Both questionnaires are widely used in cross-cultural research.

At 8 and 18 months, parents filled out SES questionnaires including their education, income, age, place of birth etc. All questionnaires were translated into Turkish by German/Turkish bilinguals and the translation was validated through reverse translation.

6.3.4 Coding

All coding was done using Interact 14 (Mangold International GmbH).

Coding for the decorated room included parents' and infants' pointing gestures. The coding scheme was based on Liszkowski and Tomasello (2011). A point was identified if the arm was either fully or half way extended toward a perceptible object or location, and had to be accompanied by looks in that direction, and the behavior could not be a clear attempt to grab or touch the object. The hand shape of the pointing gesture was distinguished as either index-finger pointing or whole-hand pointing. A point was considered to be an index-finger point when the index-finger was distinctly extended relative to all other fingers, but when this wasn't the case, the point was coded as a whole-hand point. Points were further distinguished based on whether they were temporally contingent on the point of the interactional partner. A point was considered contingent if it occurred within 10 seconds of the caregiver's point. Further coding included whether the contingent point was directed at the same object as the preceding point by the interaction partner.

The coding scheme for free play and the interactions at home was the same, and included all deictic gestures executed by the infant~~,~~ and all other persons present.

Deictic gestures included pointing gestures (consisting of index-finger point and whole-hand point (analogous to the coding for the decorated room), and showing gestures (analogous to Cameron-Faulkner et al., 2015) as well as requesting gestures. A showing gesture was coded if an infant held an object into the field of vision of his/her parents with the intention to direct the parents' attention towards the object. Parents could respond by either taking the object or not and in the case of the latter, the object could be placed/thrown by the infant within the proximity of the parents. The arm could be stretched or bent and afterwards the infant could retrieve the object. Lastly, requesting objects either in the form of reaching for the object with a clear communicative intent, identified by looking back and forth between the object and the interaction partner using reaching and begging gestures (holding out the open hand, palm up) were also coded. If showing gestures initiated a ritualized game like passing a ball back and forth, only the initiating gesture was counted. Gestures that were part of an action like building a tower out of blocks were also coded similarly. All gestures by caregivers were also classified into two categories, based on whether they were directed towards objects the infant was focusing on ("matching") or whether they were directed at objects outside the infants' frame of attention ("redirecting").

The first 15 minutes of home observations were omitted, since behavior in this time frame might be especially susceptible to reactivity effects. Furthermore, videotaping was often interrupted due to problems with the infant head-camera, thus a code of visibility was added and subtracted from the recording time, and all behavior standardized by the overall time infant and parent were visible on the recording. Since some home-visits (N=10) had to be ended before 60 minutes of interaction could be recorded (due to the infant falling asleep) subjects with visible video time of less than 30 minutes in at least one of the sessions were omitted from analyses. We calculated gestures per hour in order to account for this variance. We did so by dividing the amount of gestures by the respective visible video time in seconds and by multiplying with 3600.

For free play, all five minutes of recording were analyzed.-As the recording was done by four cameras simultaneously, a code of visibility was not needed.

The live-coding of interaction formats at home (scan sampling) included three main categories: individual activity (where the infant did not interact with another person), dyadic interaction (where the infant interacted with one other person but without an object or a third interaction partner, i.e. comforting or physical affection) and triadic interaction (where the infant and one other person jointly attended to an object or another person, i.e. book-reading, playing with toys). The joint attention to an object or a third person could be identified through gestures, speech or gaze alternations (see Salomo & Liszkowski, 2013).

The age of emergence (AoE) of a gesture for any infant was defined as two observed gestures in two consecutive months similar to the AoE of index-finger pointing in the decorated room.

6.3.4.1 Reliability.

Cohen's Kappa (κ) was used as a measure of overall inter-rater agreement as well as for each code category separately. Matching and redirecting gestures were coded separately and coded gestures were tagged with either a matching or redirecting tag. Kappa for matching/redirecting (based on 13 videos) was .955, which is substantial. Overall, Kappa was acceptable (see table 6-4).

Table 6-4. Interrater Reliability

Measure	*N* videos coded (per coder)	*N* coder	κ points (Range)	κ showing gestures (Range)	κ requesting gestures (Range)	κ overall (Range)
Decorated room	40 (10)	4	.90 (.79-1)	-	-	.90 (.84-.98)
Free play	40 (10)	4	.81 (.79-.86)	.82 (.81-.85)	.83 (.72-1)	.82 (.82-.87)
Home visits	30 (10)	3	.76 (.73-.79)	.86 (.85-.88)	.7 (.69-.73)	.83 (.82-.86)

Note. To increase clarity, mean Kappa across coders is reported

6.3.5 Statistical Analyses

Statistical analyses were conducted using SPSS 22. We used general linear models for repeated measures and paired-sample T-tests for longitudinal development as well as Pearson Product-Moment correlation analyses as a measure of longitudinal stability and for any predictors of the AoE of index-finger pointing, infants' ability to use the pointing gesture at 11 months and language abilities at 18 and 26 months (one-sided since we predicted positive correlations between the means of the different measures, negative correlations predicting the AoE of index-finger pointing and positive correlations predicting language and infants ability to use the index-finger pointing gesture at 11 months). All correlation analyses were controlled using Monte Carlo simulations as well as controlled for potential outlier. All p-values reported are the Monte Carlo significances based on 10.000 sampled tables. Throughout the statistical analysis, Greenhouse-Geisser corrected degrees of freedom and p values were used for violations of sphericity. Due to the sample size and non-normal distributions, we included median split analyses (below and at median vs. above median). Mediation analyses were conducted using SPSS 22 with the PROCESS

Model (Hayes, 2012). Since this meant highly reduced samples and a higher likelihood of non-normal distributions, we included bootstrapping (5000 samples) in the analyses.

6.4 Results

The results section is divided into three parts to answer our three main questions. The first section concerns comparability of the three different methods to sample interaction and index-finger pointing in particular, and also contains descriptive data on the frequency of use of the different gestures and the age of onset of infants' index-finger pointing and showing gestures, in the decorated room, during free play, and at home. The decorated room only assessed infants' and parents' use of the pointing gesture, while free play sessions and home-visits also covered other deictic gestures. We also included analyses on the longitudinal development of these gestures. Next, we directly compare the frequency of gesture use across settings. Further, we compare gesture use, using concurrent correlation analyses both on overall frequency and by dividing the sample into two groups of low and high gesture to see whether there is a similar pattern of use even if overall frequency differs. Lastly, we also include controls on potential group differences due to infant gender, cultural background or SES.

The second section concerns our other question, on whether parental input is predictive of the age of onset of index-finger pointing, while also controlling for intra-individual predictors like infants' use of whole-hand pointing and showing gestures.

In the third section, we report the results of our attempt to replicate earlier findings earlier findings on the influence of infants' use of index-finger pointing gestures on later language abilities. Lastly, we assessed whether any of the predictors of the AoE of index-finger pointing were also predictive of later language abilities and if they were, we controlled for potential mediating effects from the age of onset of index-finger pointing.

6.4.1 Comparing parents' and infants' gesture use in the decorated room, during free play and at home

6.4.1.1 Development of pointing in the decorated room.

No infant used index-finger pointing gestures during the first visit at 8 months. The use of index-finger pointing increased significantly from 8 to 14 months (see table 6-5).

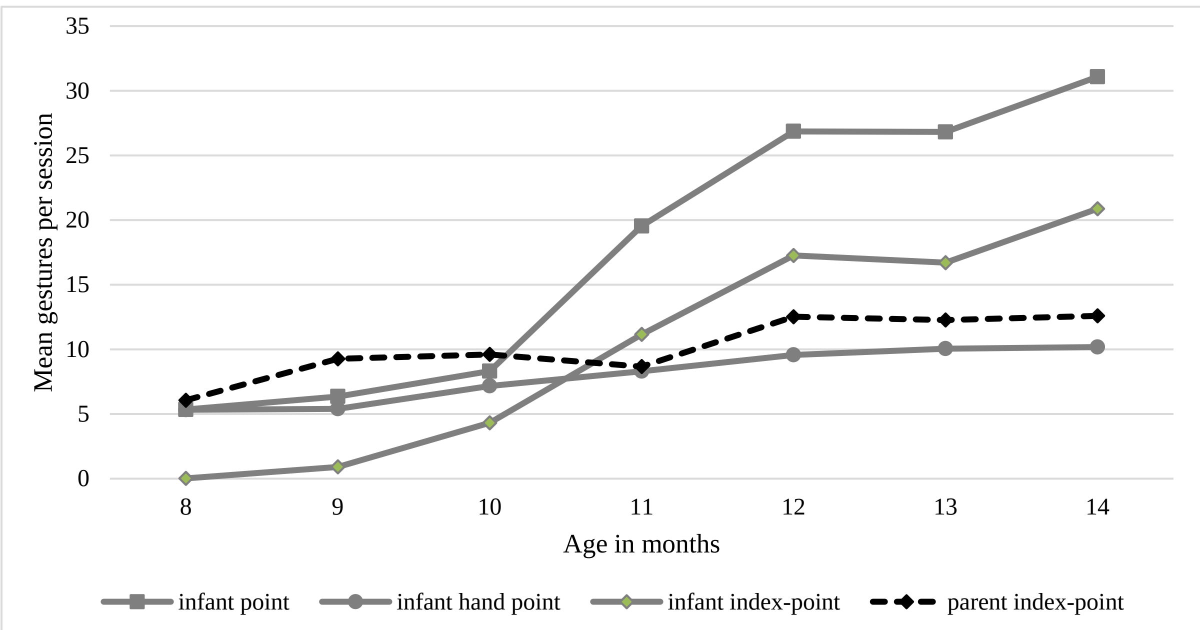

Figure 6-1. Parents' and infants' pointing in the decorated room from 8 to 14 months

Four infants never used any index-finger points in the decorated room, though two of them dropped out at 10 and 11 months respectively so no data on later gestures is available. The use of index-finger pointing increased significantly from 8 to 14 months (see table 6-5).

Most infants already used hand points during the first session at 8 months (N=34). While there was no main effect of age in the ANOVA there was a significant increase in whole-hand pointing gestures between 8 and 14 months (see table 6-5).

Table 6-5. ANOVAs (main effect of age) and T-test for pointing in the decorated room from 8 to 14 months

	Gesture	ANOVA repeated measures				Paired samples t-test (8 to 14 months)		
		F	*df*	*p*	ηp^2	*t*	*df*	*p*
Infant	pointing	21.14	3.93, 21	<.001	.45	-10.41	38	<.001
	hand pointing	1.18	6, 21	.32	.04	-2.27	38	.029
	index-finger pointing	12.39	2.34, 21	<.001	.32	-7.08	38	<.001
Parent	index-finger pointing	3.44	4.15,21	.01	.12	-5.28	38	<.001

All but one parent used index-finger pointing in the decorated room during at least one session. Parental index-finger pointing also increased significantly over time (see table 6-5).

There was a high amount of intra-individual stability of gesture use in the decorated room. Index-finger pointing was highly inter-correlated beginning with index-finger pointing from 9 to 10 months (all $r<.357$, all $p>.035$). Hand pointing was similarly correlated across months (all $r>.394$, all $p<.017$). Parental pointing was also highly correlated across months (all $r>.565$, all $p<.001$).

6.4.1.2 Development of deictic gestures during free play.

Infants used very few points during free play (see figure 6-2). At 8 and 9 months, there were no index-finger points and less than .05 points on average (the highest amount of points for any infant was 1 point at 8 months and 2 points at 9 months). While parents used more points than infants during free play the average number of points only increased from 1 point on average at 8 months (range 0-8) to 4.212 (range 0-14) points on average at 18 months. The most frequent deictic gestures used both by parents and infants were showing gestures.

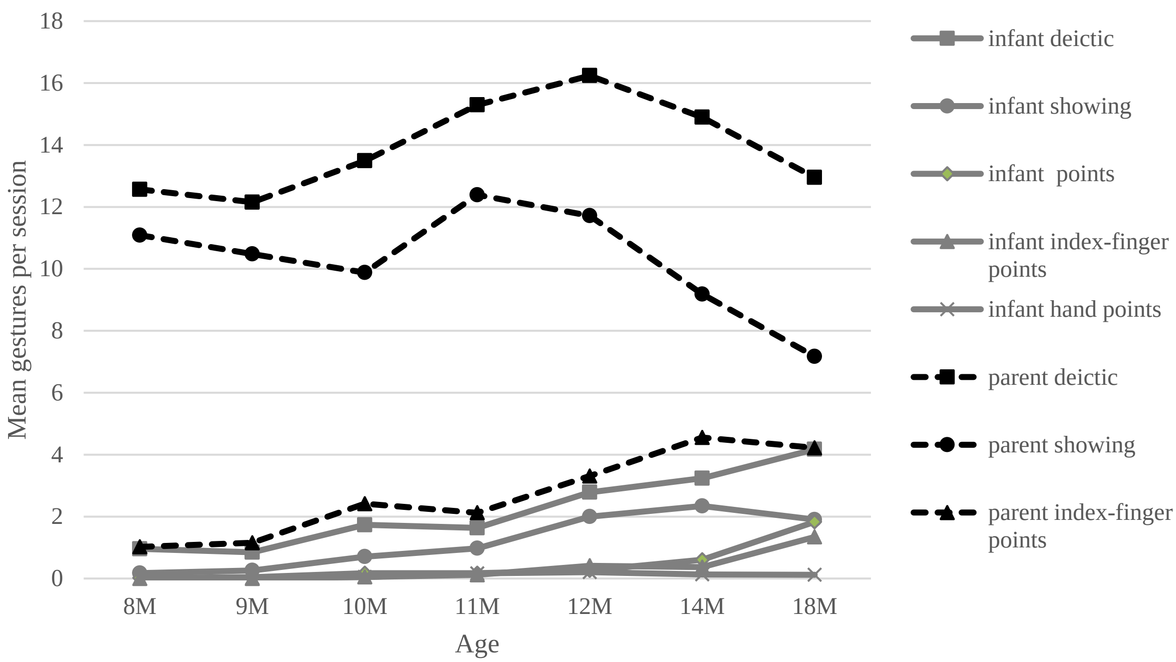

Figure 6-2. Deictic gesture use during free play

Note. Pointing = index-finger points + hand points; deictic= points + showing + requesting

All infant gestures except for whole-hand pointing increased significantly over time (see table 6-6). Parental deictic gestures did not increase significantly from 8 to 18 months. However, there was a significant increase from 8 to 12 months ($t(41)=-2.59$, $p=.013$), and a significant decrease from 12 to 18 months ($t(39)=2.79$, $p=.008$). Parental showing gestures actually decreased from 8 to 18 months. The only parental gesture that actually increased significantly from 8 to 18 months was parental index-finger pointing.

Table 6-6. ANOVAs and T-Tests for gesture use during free play from 8 to 18 months

	Gesture	ANOVA repeated measures				Paired samples t-test (8 to 18 months)		
		F	*df*	*p*	ηp^2	*t*	*df*	*p*
Infant	deictic	7.67	3.25, 22	<.001	.22	-4.75	40	<.001
	showing	6.52	4.03, 22	<.001	.19	-5.6	40	<.001
	pointing	10.81	1.77, 22	<.001	.29	-4.95	40	<.001
	index-finger pointing	7.73	2.15, 22	.001	.24	-4.12	40	<.001
	hand pointing	1.14	2.72, 22	.34	.04		40	
Parent	deictic	2.18	6, 22	.047	.07	0.02	40	.99
	showing	2.7	6,22	.016	.09	2.98	40	.005
	index-finger pointing	4.75	3.82, 22	<.001	.15	-5.17	40	<.001

There was very little intra-individual stability across months for infants' gesture use during free play. Deictic gestures were only correlated across months from 9 months to 10 months ($r(41)=.31$, $p=.046$) and 10 months to 11 months ($r(36)=.34$, $p=.045$). Infant showing gestures were only correlated from 12 to 14 months ($r(37)=.36$, $p=.029$). Infant index-finger points were not correlated across months (all r<.13, all p>.46). However, from 8 to 12 months parental deictic gesture use was highly correlated across months (all r>.42, all p<.008). There were no significant correlations from 12 to 14 months ($r(37)=.27$, $p=.104$) and 14 to 18 months ($r(36)=.11$, $p=.52$). This pattern stayed the same when only including those families, where the same parent attended all sessions. Results for showing gestures were very similar with significant month-to-month correlations from 8 to 12 months (all r>.47, all p<.003) and no significant correlations from 12 to 14 months ($r(27)=.24$, $p=.152$) and 14 to 18 months (r(36)=.12, p=.482). Parents' use of the index-finger pointing gesture was only significantly correlated from 9 to 10 months ($r(41)=.33$, $p=.032$) and 10 to 11 months ($r(36)=.61$, $p<.001$).

6.4.1.3 Development of deictic gesture use and interaction formats at home.

Due to the fact that only one camera was available for coding, which was focused on the infant, and visibility was often poor for parents' gestures, we included all pointing gestures for parents (because often hand shape could not be ascertained with a high degree of certainty). While showing gestures were the most frequently used gestures at home both by infants and parents at 8 and 10 months, pointing gestures were the most frequently used deictic gesture at 18 months by infants (see figure 6-3).

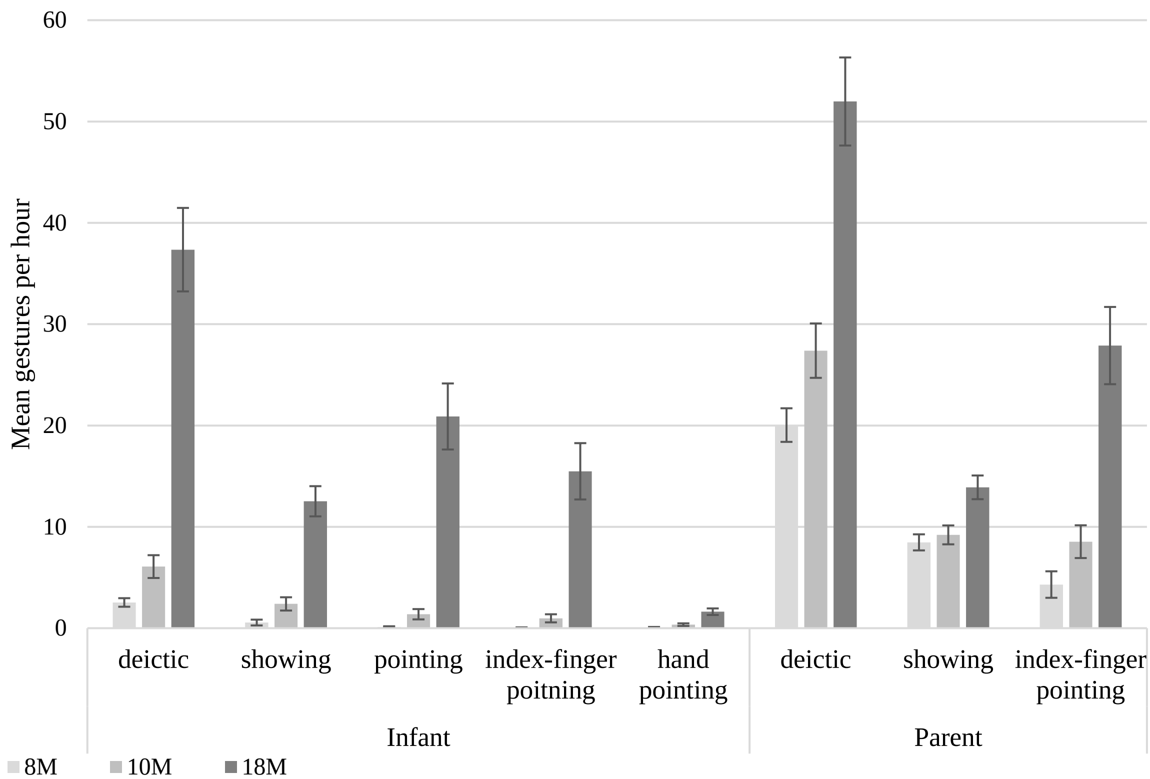

Figure 6-3. Gesture use during home visits

Note. Pointing = index-finger points + hand points; deictic= points + showing + requesting

All infant gestures significantly increased in frequency from 8 to 18 months (see table 6-7). While deictic input increased overall, the frequency of showing gestures did not change significantly over time (see table 6-7). Deictic gesture use and showing gestures at home were not correlated across months (all *r*<.09, all *p*>.59). There was a significant correlation of pointing gestures from 10 to 18 months (*r*(41)=.62, p<.001). This pattern stayed the same when only looking at gestures from the primary caregiver. As for infant gestures, there was no significant session-to-session correlation for deictic gestures or showing gestures (all *r*<.23, all *p*>.13). Only infant's pointing gestures were significantly correlated from 8 months to 10 months *r*(40)=.69, *p*=.025.

Table 6-7. Repeated measures ANOVA and paired samples t-test for home-visit gestures

	Gesture	ANOVA repeated measures				Paired samples t-test (8 to 18 months)		
		F	*df*	*p*	*ηp²*	*t*	*df*	*p*
Infant	deictic	47.03	1.12, 32	<.001	.59	-8.09	37	<.001
	showing	39.21	1.41, 32	<.001	.54	-7.59	37	<.001
	pointing	28.25	1.03, 32	<.001	.46	-6.13	37	<.001
	index-finger pointing	21.05	1.03, 32	<.001	.39	-5.28	37	<.001
	hand pointing	12.41	1.16, 32	.001	.27	-4.99	37	<.001
Parent	deictic	27.03	1.71, 32	<.001	.45	-6.99	37	<.001
	showing	1.46	2, 32	.238	.07	.69	37	.496
	index-finger pointing	16.17	1.49, 32	<.001	.4	-5.34	37	<.001

The time spent in interaction at home also changed over time (See figure 6-4). There was a significant decrease in dyadic interaction across months, and a significant increase in triadic interaction across months. The amount of individual activity did not change significantly (see table 6-8).

Table 6-8. ANOVAs and T-Tests fir interaction formats during home-visits

Interaction format	ANOVA repeated measures				paired samples t-test (8 to 18 months)		
	F	*df*	*p*	*ηp²*	*t*	*df*	*p*
dyadic	12.86	2,32	<.001	.28	2.88	37	.007
triadic	19.47	1.63, 32	<.001	. 36	5.6	37	<.001
individual	2.44	2,32	.095	.07	-6.66	37	<.001

The amount of dyadic interaction did not correlate across months (all r<.045. all p>.22). The amount of triadic interaction correlated positively from 8 to 10 months ($r(41)=.62$, $p<.001$) but not from 10 to 18 months ($r(37)=.27$, $p=.101$). The amount of individual activity did not correlate from 8 to 10 months ($r(41)=-.18$, $p=.27$) but was positively correlated from 10 to 18 months ($r(37)=.46$, $p=.005$).

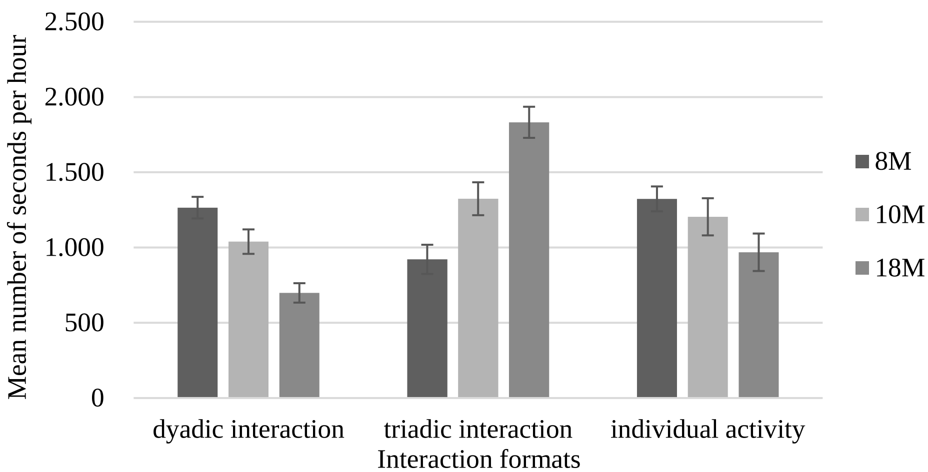

Figure 6-4. Interaction formats during home visits

Age of emergence of index-finger pointing

We calculated the age of emergence (AoE) of index-finger pointing in the decorated room, at home, and during free play. Since we only had three data points for home-visits, the results cannot be directly compared to the other two settings. The median AoE of index-finger pointing in the decorated room was 11 months. 8 infants (17%) never used two pointing gestures in two consecutive months in the decorated room (see Table 6-9). The median AoE for home-visits was 18 months but 9 infants (20%) never used two pointing gestures during any home-visit. The median AoE of index-finger pointing during free play was 14 months, however, only 15 infants (32%) ever used two index-finger points or more during one session. All infants first started using the index-finger pointing gesture in the decorated room.

Table 6-9. Age of Emergence of index-finger pointing per setting

	Decorated Room		Home-visit		Free Play	
Age	***N***	***%***	***N***	***%***	***N***	***%***
8 months	0	0	0	0	0	0
9 months	3	6.5	-	-	0	0
10 months	10	21.7	7	15.2	0	0
11 months	7	15.2	-	-	1	2.2
12 months	10	21.7	-	-	2	4.3
13 months	4	8.7	-	-	3	6.5
14 months	4	8.7	-	-	9	19.6
18 months	-	-	30	65.2	0	0
overall	38	82.6	37	80.4	15	32.6
missing	8	17.4	9	19.6	31	67.4

Age of emergence of showing gestures

The AoE of showing gestures was calculated analogously to the AoE of index-finger pointing. The AoEs for home visits and free play can be found in table 6-10, however, since there were only three time points for testing, the results have to be viewed with caution. The median AoE during Free Play was 12 months while the median AoE for home visits was 10 months. 12 infants showed showing gestures earlier at home than during free play.12 infants used showing gestures at home but never during free play and 4 infants used showing gestures during free play but not during home visits.

Table 6-10 Age of emergence of showing gestures

	Home-visit		Free Play	
Age	***N***	***%***	***N***	***%***
8 months	5	10.9	1	2.2
9 months	-	-	3	6.5
10 months	16	34.8	3	6.5
11 months	-	-	6	13
12 months	-	-	12	26.1
14 months	-	-	3	6.5
18 months	17	37	3	6.5
overall	38	82.6	31	67.4
missing	8	17.4	15	32.6

6.4.1.4 Parental responsiveness.

As a measure of parental responsiveness, we used two further codes. For the decorated room this was the proportion of parents' points that were temporally contingent with the point of the infant (within 10s) and directed at the same object the infant had previously pointed a ("referential uptake"). For free play and home visits this was the proportion of parental deictic gestures aimed at the same object the infant was attending to ("responsive gestures"). Descriptive data for parents' responsiveness can be found in table 6-11.

Table 6-11. Descriptive statistics on parental referential uptake and responsive gestures

	Age	*N*	Min.	Max.	Mean	*SE*
Home-visits (responsive gestures)	08 months	41	.33	1.00	.68	.021
	10 months	41	.21	1.00	.72	.029
Free play (responsive gestures)	08 months	45	.00	1.00	.78	.031
	09 months	46	.00	1.00	.79	.029
	10 months	41	.00	1.00	.79	.031
	11 months	41	.38	1.00	.82	.026
	12 months	42	.00	1.00	.8	.030
Decorated room (referential uptake)	08 months	30	.00	.5	.06	.02
	09 months	38	.00	.4	.04	.014
	10 months	32	.00	1.00	.16	.041
	11 months	34	.00	1.00	.22	.042
	12 months	37	.00	.5	.15	.023
	13 months	36	.00	.75	.22	.034
	14 months	37	.00	.88	.21	.033

6.4.1.5 Group level differences.

Before directly comparing the different settings, we controlled for potential group differences. There was no systematic effect of gender, thus data were collapsed across gender for further analyses. Next, we looked at potential group level differences on account of cultural backgrounds. First, we compared data on cultural self-construal and socialization goals. Values for SG and SCS can be found in table 6-12. Values were recorded with 7 point Likert style items.

Table 6-12. Mean scores and difference scores for cultural self-construal (SCS) and socialization goals (SG)

	N	*Min.*	*Max.*	*M*	*SD*
SCS Independent	36	52	89	69.13	9.38
SCS Interdependent	36	50	130	68	12.9
SCS difference score	35	-57	24	.82	14.86
SG Independent	36	28	70	54.8	8.74
SG Interdependent	36	25	67	48.33	9.67
SG difference score	36	-19	2	6.47	9.57

We reported mean scores per subscale as well as difference scores (independent-interdependent). The samples did not differ on cultural self-construal and socialization goals (all $p<.12$)

Table 6-13. Significant results of T-Tests on group level differences between German and Turkish-German dyads

Measure	Infant age (months)	cultural background	mean	*mean difference*	*t*	*df*	*p*
Free Play- parental deictic gestures	8	Turkish	17.57	*7.19*	2.24	16.8	.039
		German	10.37				
	9	Turkish	19.07	9.94	3.96	44	<.001
		German	9.12				
	10	Turkish	21.08	10.73	4.31	39	<.001
		German	10.34				
	11	Turkish	19.42	6.28	2.86	18.82	.022
		German	13.14				
	12	Turkish	21.50	7.19	3.2	40	.003
		German	14.13				
Free Play- parental showing gestures	9	Turkish	16.28	8.34	4.12	44	<.001
		German	7.93				
	10	Turkish	13.66	5.35	2.86	39	.007
		German	8.31				
	11	Turkish	16.42	6.13	3.15	39	.003
		German	10.29				
	12	Turkish	16.00	6.0	3.46	40	.001
		German	10.00				
Home visits - parental deictic gestures	8	Turkish	27.28	2.96	10.1	42	.005
		German	17.18				

Next we compared infants' and parents' behaviors across the two groups. All significant differences can be found in table 6-13. One major difference was the amount of deictic input during free play from 8 to 12 months, as well as showing gestures in particular, with Turkish-German parents using significantly more gestures each month.

Lastly, we analyzed potential differences due to parental education or family income, splitting the sample into two groups of similar size with one group consisting of primary caregivers with a master's degree or higher and the other group consisting of primary caregivers with a bachelor's degree or lower (or above and below median income respectively). There were no systematic effects of parental education or family income.

6.4.1.6 Interrelations between laboratory and home gestures.

Our first question was whether the overall frequency of gesture use was different across settings. Due to the vastly different lengths of observation, these results have to be viewed with caution. We scaled up the deictic gestures during free play to match the hour of observation at home (gestures/300sec)*3600sec) in order to run T-tests comparing the amount of gestures in both settings. Parents used more deictic gestures (overall as well as showing gestures, pointing gestures and index-finger pointing gestures) during free play than they did at home (all $p<.018$). As for infants' use of deictic gestures, there were no significant differences in the frequency of pointing gestures or index-finger pointing gestures (all $p>.5$). However, children used significantly more deictic gestures during free play at 8 ($t(43)=-4.39$, $p<.001$) and 10 months ($t(38)=-3.03$, $p<.001$), but not at 18 months ($t(37)=-1.65$, $p=.11$). Infants' showing gestures differed significantly at 10 months ($t(39)=-2.28$, $p=.028$) and 18 months ($t(37)=-2.46$), $p=.019$) while the difference at 8 months approached significance ($t(43)=-2.01$, $p=.051$).

How much did parents and infants actually interact using toys at home? The mean amount of triadic interaction with toys at home at 8 months was 13.06 minutes over the span of one hour (*min*=.14, *max*=49.41, *SD*=9.06) at 10 months the mean was 18.4 Minutes (*min*=3.38, *max*=39.64, *SD*=11.19) and at 18 months the mean was 20.26 Minutes (*min*=5.10, *max*=41.57, *SD*=11.6). The mean amount of toy play, where the infant was interacting with toys on their own, was 13.02 minutes at 8 months (*min*=.44, ma*x*=30.49, *SD*=8.21) and 9.74 minutes at 10 months (*min*=1.46, *max*=26.21, *SD*=6.34). At 18 months the mean amount of individual toy play was 8.49 minutes (*min*=0, *max*=27.51, *SD*=6.57).

At 8 months, parents used more responsive gestures during free play than at home ($t(39)=2.86$, $p=.007$). At 10 months the difference was not significant ($t(38)=-1.56$, $p=.13$). This pattern stayed the same when only including the gestures from the primary caregiver (at 8 months $t(39)=3.16$, $p=.003$, at 10 months $t(38)=1.41$ $p=.17$).

Infants used significantly more pointing gestures (hand pointing and index-finger pointing combined) in the decorated room than during free play from 8 months onwards (all $p<.001$). The same was true for index-finger pointing in particular, as well as whole-hand pointing (all $p<.001$). The same was true for parents' pointing (all $p<.001$).

Our next question was, whether infants' and parents' behaviors were comparable across the different settings, even if overall frequency differed, using concurrent correlation analyses both for overall frequency and for splitting the sample into two groups using median splits of high and low gesture use and comparing these.

First, we tested whether caregivers' frequency of deictic gestures was correlated concurrently at home and in the laboratory at 8, 10 and 18 months. The only significant concurrent correlation was found at 8 months ($r(44)=.368$, $p=.014$). Second, we tested whether showing gestures were concurrently correlated. The only significant concurrent correlation was at 18 months ($r(38)=.355$, $p=.029$). Third, we analyzed concurrent correlations between index-finger pointing gestures at home, during free play and the decorated room. The frequency of pointing gestures during the home visits was not correlated with index-finger pointing in the decorated room (all $r<.17$, all $p>.27$) or during free play (all $r<.13$, all $p>.39$). However the frequency of index-finger pointing in the decorated room and during free play was concurrently correlated at 9 months, ($r(45)=.31$, $p=.037$) and 10 months ($r(41)=.56$, $p<.001$).

The amount of responsive gestures at home and during free play was not concurrently correlated, neither at 8 months ($r(40)=.04$, $p=.78$) nor at 10 months ($r(39)=.16$, $p=.33$). The same pattern emerged when only including the primary caregivers' gestures at home (8 months $r(40)=-.057$, $p=.72$, at 10 months $r(39)=.08$, $p=.64$). No further correlations were found using median splits (all $\varphi<.25$, all $p>.12$).

Infant deictic gestures were concurrently correlated at 10 ($r(39)=.37$, $p=.02$) and 18 months ($r(38)=.39$, $p=.013$). Infant showing gestures were concurrently correlated at 8 months ($r(44)=.53$, $p<.001$) and 10 months ($r(39)=.67$, $p<.001$). No further correlations were found when using median splits (all $\varphi<.21$, all $p>.194$).

Since little or no infant pointing gestures were recorded during free play until infants were 14 months old (even at 14 months 25 out of 46 infants did not use any pointing gestures), we only used median split analyses to compare infant pointing during free play with infant pointing in the decorated room and at home at 14 and 18 months. Pointing gestures during free play and at home were concurrently correlated at 18 months ($\varphi(38)=.48$, $p=.003$). Infant pointing during free play and in the decorated room at 14 months was not significantly correlated ($\varphi(37)=.03$, $p=.85$).We compared infant pointing at home and in the decorated room at 10 and 18 months since at 8 months only one infant used a pointing gesture at home. Infants' use of pointing gestures at home and in the decorated room was significantly correlated ($r(41)=.57$, $p<.001$). This was also true for index-finger pointing in particular ($r(41)=.47$, $p=.002$).

6.4.1.7 Summary: Comparing parents' and infants' gesture use across settings.

Overall gesture use increased from 8 to 18 months both for caregivers and infants across all three settings. Index-finger pointing gestures were most frequently and earliest found in the decorated room. Only few index-finger pointing gestures were recorded during free play. As for the control analyses, there were no systematic effects of gender, however there were significant differences in gesture use between German and Turkish-German caregivers, with Turkish-German caregivers using significantly more deictic gestures during free play from 8 to 12 months as well as at home at 8 months. Comparing parents' and infants' gesture use across settings, we found very few correlations for parents' gesture use, meaning parents showed different patterns of behavior in the laboratory compared to the home observations, while infants' behaviors were more frequently correlated across settings.

6.4.2 Predicting the AoE of Index-finger pointing

We used both the overall frequency of the respective behaviors to predict the AoE of index-finger pointing as well as using median splits (<=1, >2) to predict whether infants were index-finger pointers at 11 months (the median age of onset of index-finger pointing). We first tried to replicate the results from Rüther & Liszkowski (submitted) using the frequency of parental pointing in the decorated room to predict the AoE of index-finger pointing, as well as the fact whether infants were index-finger pointer at 11 months. We then assessed parental pointing at home, we did not include parental pointing during free play since the setting had been shown to elicit very little pointing behavior. We also included parental showing gestures as well as the amount of triadic interaction at home as potential predictors of the AoE of index-finger pointing and whether infants were pointer at 11 months. Further we attempted to replicate earlier results from Rüther & Liszkowski (submitted) and Cameron-Faulkner et al. (2015) on significant correlations between infant whole-hand pointing and showing gestures and the AoE of index-finger pointing.

6.4.2.1 Parent pointing predicting the AoE of index-finger pointing.

While parental pointing at 8 months was not significantly correlated with the AoE of index-finger pointing ($r(38)=-.25$, $p=.065$), parental pointing at 9 months was a significant predictor $r(37)=-.34$, $p=.015$) as was parental pointing at 10 months ($r(33)=-.45$, $p=.009$). Neither parental pointing at 8 , 9 or ten months, using median splits, was significantly correlated with infants' status as index-finger pointer at 11 months (for 8 months $\varphi(39)=.07$, $p=.32$, for 9 months $\varphi(38)=.08$, $p=.31$, for ten months ($\varphi(35)=.23$, $p=.229$).

Next we assessed whether the same results could be found for parental pointing at home. Parental pointing at 8 months was significantly correlated with the AoE of index-finger pointing ($r(36)=-.43$, $p=.003$) and the same results were found when using median splits ($\varphi(38)=.32$, $p=.025$). The same was true for parental pointing at 10 months ($r(33)=-.42$, $p=.007$; $\varphi(35)=.31$, $p=.034$)

6.4.2.2 Parent showing gestures predicting the AoE of index-finger pointing.

The frequency of parents' showing gestures during free play was not predictive of the AoE of index-finger pointing at 8 months ($r(38)=.14$, $p=.2$) or 9 months $r(38)=.09$, $p=.22$). However, parent showing gestures at 10 months were significantly correlated with the AoE of index-finger pointing ($r(33)=-.32$, $p=.035$). The frequency of parents' showing gestures at home at 8 months was not significantly correlated with the AoE of index-finger pointing ($r(36)=-.09$, $p=.31$), however at 10 months the correlation was significant (*r*(33)=-.36, *p*=.019). The same was true when using median splits (*φ*(35)=.31, *p*=.034). There were no further correlations using median splits to predict whether infants were index-finger pointer at 11 months (for showing gestures during free play at 8 months *φ*(39)=-.08, *p*=.33, at 9 months *φ*(39)=.02, *p*=.44, and at 10 months *φ*(35)=.14, *p*=.404, for showing gestures at home at 8 months *φ*(38)=.16, *p*=.16).

6.4.2.3 Triadic interaction predicting the AoE of index-finger pointing.

The amount of triadic interaction at home at 8 months was not predictive of the AoE of index-finger pointing (*r*(37)=-.25, *p*=.057) though the relation approached significance. However, the amount of triadic interaction at 10 months was significantly correlated with the AoE of index-finger pointing (*r*(33)=-.49, *p*=.003). There was no significant correlation between triadic interaction at 8 months split into two groups using the median and whether infants were pointer at 11 months (*φ(*37*)*=.09, *p*=.3), at 10 months the correlation was significant (*φ(*37*)*=.35, *p*=.035)

6.4.2.4 Infant hand pointing and showing gestures predicting the AoE of index-finger pointing.

Only very few infants used showing gestures during free play (*N*=7 at 8 and 9 months, *N*=9 at 10 months) thus they were not included as potential predictors of the AoE of index-finger pointing or whether infants were index-finger pointer at 11 months. Similarly, only 6 infants used showing gestures at home at 8 months. However, at 10 months, at least half of the infants used showing gestures at home (*N*=21). However, since the overall frequency was still low, infants were split into two groups (whether they used at least one showing gesture or not) in order to predict whether they were index-finger pointer one month later. The correlation was not significant (*φ*(35)=.26, *p*=.065) though it approached significance.

The frequency of infants' whole-hand points in the decorated room at 8 and 9 months was not significantly correlated with the AoE of index-finger pointing (for 8 months *r*(38)=-.25, *p*=.071, for 9 months *r*(37)=-.08, *p*=.623). However, using median splits, infant whole-hand pointing at 8 months was significantly correlated with whether infants were index-finger pointer at 11 months (*φ*(39)=.39 *p*=.015) but not whole hand pointing with 9 months (*φ*(37)=.24, *p*=.07) though this correlation approached significance. Infant whole-hand pointing gestures at 10 months were not significantly correlated with the AoE of index-finger pointing (*φ*(35)=.14, *p*=.19)

6.4.2.5 Parent responsiveness and referential uptake predicting the AoE of index-finger pointing.

The proportion of responsive gestures at home when infants were 8 or 10 months old was not predictive of the AoE of index-finger pointing (for 8 months *r*(38)=-.03, *p*=.42, for 10 months *r*(22)=.15, p=.19). Neither was the proportion of responsive gestures during free play at 8 months (*r*(38)=-.054, *p*=.37) or 9 months (*r*(33)=-.05, *p*=.39). However at 10 months the correlation was significant (*r*(33)=-.46, *p*=.003). The results stayed the same when using median splits to predict whether infants were pointer at 11 months excluding the correlation at 10 months, which was no longer significant (for responsive gestures at home at 8 months *φ*(35)=.03, *p*=.43, and at 10 months *φ(*35*)*=.036, *p*=.42, for responsive gestures during free play at 8 months *φ*(38)=.16 *p*=.17, at 9 months *φ*(39)=.13 *p*=.21, and at 10 months *φ*(35)=.26 *p*=.065).

The proportion of referential uptake in the decorated room at 8 months was significantly correlated with the AoE of Index-finger pointing (*r*(24)=-.41, *p*=.02) the correlation at nine months approached significance *r*(30)=-.29, *p*=.055) at ten months the correlation was not significant (*r*(25)=-.11, *p*=.29). The results were similar using median split analyses to predict whether infants were pointer at 11 months, however in this case the correlation at ten months was also significant (for 8 months $\varphi(25)=.42$ $p=.016$, for 9 months $\varphi(31)=.2$ $p=.1$, for 10 months $\varphi(27)=.33$, p=.043).

6.4.2.6 **Control analyses.**

We ran several control analyses. First, due to the fact that some of the infants already used index-finger pointing gestures at 10 months (*N*=13), we re-ran the significant predictive correlation analyses only including those infants who did not yet use index-finger pointing gestures at 10 months. Second, we confirmed whether any of the predictors were inter-correlated and if so, used partial correlation analyses. Third, since the Turkish-German parents used significantly more gestures during free play, we re-ran the correlation analyses concerning the input during free play including only the German sub-sample.

6.4.2.6.1 Predictors at 10 months.

The sub-sample of infants who did not yet use the index-finger pointing gesture at 10 months was significantly reduced (*N*=20-22, depending on the measure), making the analyses much more difficult. Only parent pointing in the decorated room and parent responsiveness during free play remained significant (see table 6-14).

Table 6-14. Results of confirmatory correlation analyses on infant with an AoE of index-finger pointing of 11 months or higher

age	measure	*r*	*p*	*N*
11 months or higher	DR parent index-finger pointing	-.5	.012	20
	FP parent showing	-.19	.217	20
	FP parent responsiveness	-.62	.001	20
	HV parent showing	-.19	.207	21
	HV parent pointing	-.29	.1	21
	HV triadic interaction	-.26	.143	22

As a second measure we ran independent samples t-tests, including the grouping variable of infants who used index-finger pointing gestures at 10 months. There was a significant difference for parent pointing at home at 10 months and triadic input at home at 10 months (See table 6-15).

Table 6-15. Results of an independent samples t-test using infants' ability to use the index-finger pointing gesture at 10 months to compare deictic input

	t	*df*	*p*	Mean Difference	*SE*
DR parent index-finger pointing	-.35	39	.727	-.96	2.7
FP parent responsiveness	.87	39	.389	.05	.06
FP parent showing	-1.64	39	.109	-2.97	1.81
HV parent pointing	-2.65	27.48	.013	-8.35	3.16
HV triadic interaction	-2.97	39	.005	-690.8	232.3
HV parent showing	-1.30	37	.201	-4.37	3.35

As for the correlations using median splits, only one correlation remained significant when excluding those infants who already used the index-finger pointing gesture at 10 months, parent responsiveness during free play (see table 6-16).

Table 6-16. Results of confirmatory correlation analyses on infant with an AoE of index-finger pointing of 11 months or higher

age	measure	*φ*	*p*	*N*
11 months or higher	DR referential uptake	0	1	10
	FP parent showing	.2	.212	20
	FP parent responsiveness	.62	.007	20
	HV parent showing	.17	.243	21
	HV parent pointing	.29	.116	21
	HV triadic interaction	.2	.193	22

Since this calculation also meant a drastic decrease in sample size we ran concurrent correlation analyses between a binary variable of infants who used index-finger pointing gestures at 10 months and the predictors at 10 months. All predictors were correlated with infants' ability to use the index-finger pointing gesture at 10 months, except parent responsiveness during free play and parent showing gestures at home at 10 months (see table 6-17).

Table 6-17. Correlation analyses of predictors and infants' ability to use the index-finger pointing gesture at 10 months (both binary)

age	measure	*φ*	*p*	*N*
10 months	DR referential uptake	.44	.007	32
	FP parent showing	.27	.043	41
	FP parent responsiveness	-.07	.32	41
	HV parent showing	.23	.074	39
	HV parent pointing	.33	.016	39
	HV triadic interaction	.46	.003	41

6.4.2.6.2 Inter-correlations of predictors.

As for potential intercorrelations between the predictors, previous analyses had revealed no concurrent correlations for parental gestures at 10 months within each behavioral category (i.e. pointing). However, there were several related predictors across behavioral categories.

Parental index-finger pointing in the decorated room was correlated form 9 to ten months ($r(39)=.67$, $p<.001$). When controlling for parental index-finger pointing at 9 months, the correlation between index-finger pointing at 10 months and the AoE of index-finger pointing remained significant ($r(par)=-.33$, $p=.036$). In turn, when controlling for index-finger pointing at 10 months, the relation between index-finger pointing at 9 months and the AoE of index-finger pointing was no longer significant ($r(par)=-.05$, $p=.38$).

While parental pointing at home at 8 months was significantly correlated with parental index-finger pointing in the decorated room at 9 and 10 months, these relations were due to a single outlier, and after deletion the correlation was no longer significant (for parental index-finger pointing in the decorated room at 9 months $r(41)=.08$, $p=.624$; and at 10 months $r(41)=.05$, $p=.752$). No other predictive correlations were found (all $r<.25$, all $p>.069$).

At 10 months, several of the predictors were intercorrelated concurrently (see table 6-18).

Table 6-18. Intercorrelation of predictors at 10 months

	1	2	3	4	5
1. DR parent index-finger pointing		.347**	.267°	0.13	.264*
2. FP parent responsiveness			.357**	0.036	.361**
3. HV parent showing gestures				.329*	.638***
4. HV Parent pointing gestures					.483***
5. HV triadic interaction					

Note. p<.001***, *p*< .01**,*p*< .05*

When running partial correlation analyses (see table 6-19), only parental pointing and showing gestures at home were no longer significantly correlated with the AoE of index-finger pointing, when controlling for triadic interaction at 10 months.

Table 6-19. Partial correlations for predictors of the AoE of index-finger pointing

Control Variables	1.	2.	3.	4.	5.
1 HV parent showing gestures		-.385*	-.500**	-.324*	-.344*
2 DR parent index-finger pointing	-.415*		-.635***	-.388**	-.403**
3 HV triadic interaction	-.072	-.431**		-.153	-.339*
4 HV parent pointing	-.346**	-.374**	-.525***		-.457**
5 FP parent responsiveness	-.340*	-.368*	-.575***	-.439**	

Note p<.001***, *p*< .01**,*p*< .05*

As for the predictors of whether infants used index-finger pointing gestures at 11 months, parents' use of pointing gestures at home at 8 and 10 months were significantly correlated $\varphi(40)=.45$, $p=.002$). Similarly, parental pointing at home at 8 months was significantly correlated with the amount of triadic interaction at 10 months ($\varphi(42)=.38$, $p=.006$). As expected the amount of triadic interaction at home and the amount of caregivers' pointing gestures at home were significantly concurrently correlated at 10 months ($\varphi(41)=.56$, $p<.001$). At 8 months there was also a significant correlation between infants' whole-hand points and the proportion of referential uptake ($\varphi(30)=.42$, $p=.01$).

When controlling for parental pointing at home at 10 months the correlation between parental pointing at home at 8 months and infants' status as pointers at 11 months was no longer significant (*rho(par)*=.18, $p=.16$). In turn, when controlling for parental pointing at home at 8 months, the correlation between parental pointing at home at 10 months and infants' status as pointers was no longer significant (*rho(par)*= .16, $p=.192$).

Using partial correlation analyses, the correlation between the amount of triadic interaction at home infants' status as pointer at 11 months was no longer significant when controlling for parental pointing at home at 10 months (*rho(par)*= .26, $p=.07$).

Similarly, when controlling for the amount of triadic interaction at home, the correlation between parental pointing at home at 10 months and infants' status as pointer at 11 months was no longer significant (*rho(par)*= .16, $p=.176$). The same was true for the correlation with parental pointing at 8 months (*rho(par)*= .21, $p=.115$). Applying partial correlation analyses by controlling for infants' whole-hand pointing at 8 months the correlation between referential uptake at 8 months and infants' status as pointer at 11 months was no longer significant, though it approached significance (*rho(par)*= .34, $p=.052$). However, the correlation between infant whole-hand pointing at 8 months and infants' status as pointer at 11 months remained significant when controlling for referential uptake at 8 months (*rho(par)*= .37, $p=.038$)

6.4.2.6.3 Control for group level differences.

Parental showing gestures during free play were still a significant predictor for the AoE of index-finger pointing when excluding the Turkish-German sample ($r(24)=-.42$, $p=.019$).

6.4.2.7 Summary: Predictors of the AoE of index-finger pointing.

The earliest predictors of the AoE of index-finger pointing were parental pointing at home at 8 months and the proportion of referential uptake of infants' hand pointing gestures at 8 months (see figure 6-5).

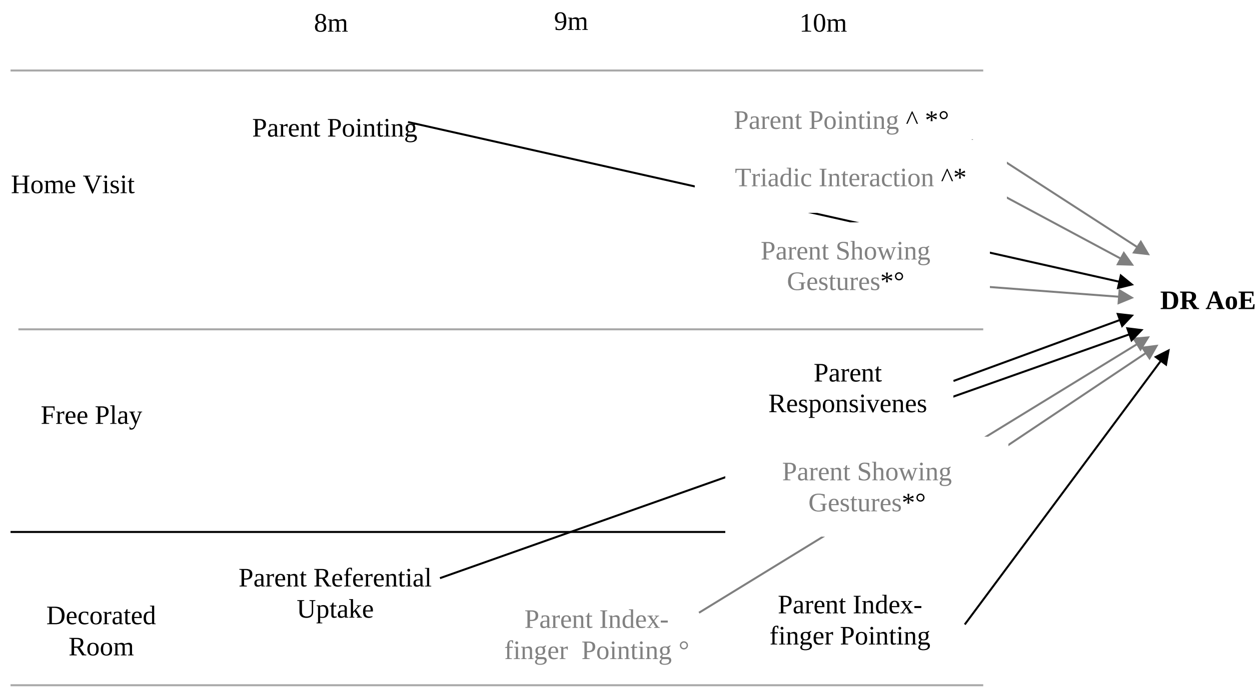

Figure 6-5. Significant predictors of the AoE of index-finger pointing including control analyses

Note. ° n.s. due to partial correlations, * n.s. for subsample AoE Index-finger pointing > 10 months, ^ significantly correlated with infant index-finger pointing in the decorated room at 10 months

At ten months the amount of triadic interaction at home (as well as the frequency of parents' pointing gestures and showing gestures) were a significant predictor (though they were no longer significant when only including infants with an AoE of index-finger pointing of 11 months or higher). Parents' pointing in the decorated room and the proportion of parents' gestures aimed at objects infants were focusing on were also significantly correlated with the AoE of index-finger pointing. After partial correlation analyses, the frequency of parents' index-finger pointing in the decorated room at 9 months, the frequency of showing gestures during free play as well as the

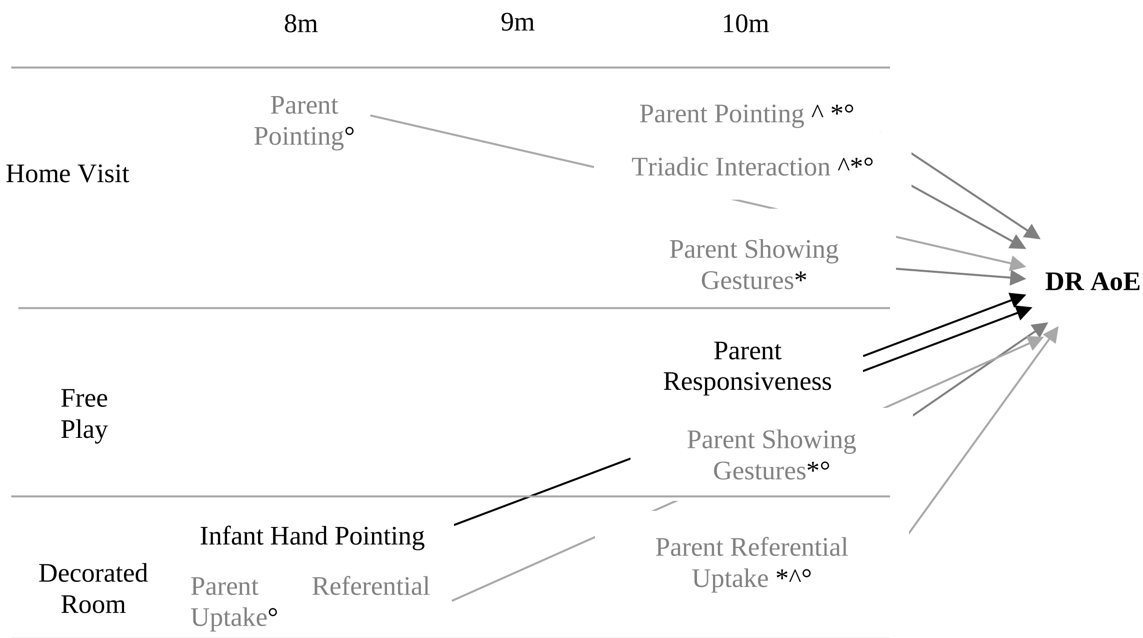

Figure 6-6. Predictors of infants' ability to use the index-finger pointing gesture at 11 months including control analyses. *Note.* ° n.s. due to partial correlations, * n.s. for subsample AoE Index-finger pointing > 10 months, ^ significantly correlated with infant index-finger pointing in the decorated room at 10 months

frequency of pointing gesture at home and the frequency of showing gestures at home at 10 months were no longer significant.

As for predicting whether infants were index-finger pointer at 11 months (i.e. using at least two index-finger pointing gestures in the decorated room), the earliest predictors were the frequency of infants' whole-hand pointing gestures as well as the amount of referential uptake by parents at 8 months in the decorated room and parents' pointing in the decorated room, though these last two were no longer significant when controlling for inter-correlations between the predictors by using partial correlation analyses (see figure 6-6). There were no significant predictors at 9 months. At ten months, the only predictor that was still significant for the sub-sample of infants with an AoE of index-finger pointing higher than 10 months was the proportion of parental gestures aimed at objects within the attentional frame of infants. Caregiver pointing and showing gestures at home as well as triadic interaction at home at 10 months, as well as parents' referential uptake in the decorated room at 10 months were not significantly correlated with infants' status as pointer at 11 months when only including the sub sample of infants with an AoE higher than 10 months.

6.4.3 Predicting Vocabulary

There was a large range of language abilities at 18 months. The minimum number of words spoken was 3 words and the maximum number was 269 words. The mean number of words spoken was 63.4 words (*SD*=77.75). A large range of productive and receptive vocabulary at this age is expected and all values were within the expected range (Szagun et al., 2014). We used raw scores that were log-transformed for predictive analyses since the manual only gives very broad percentile ranges for the vocabulary scores. At 26 months only 24 of the monolingual German infants returned for testing. Mean t-values for the three subscales can be found in figure 6-7. All infants received scores within normal limits ($t>40$). For the fourth scale, production of sentences, only raw scores are available and these were not included in the analyses. The two measures, infants' productive vocabulary at 18 months and vocabulary at 26 months were not inter-correlated (all $r<.34$, all $p>.161$).

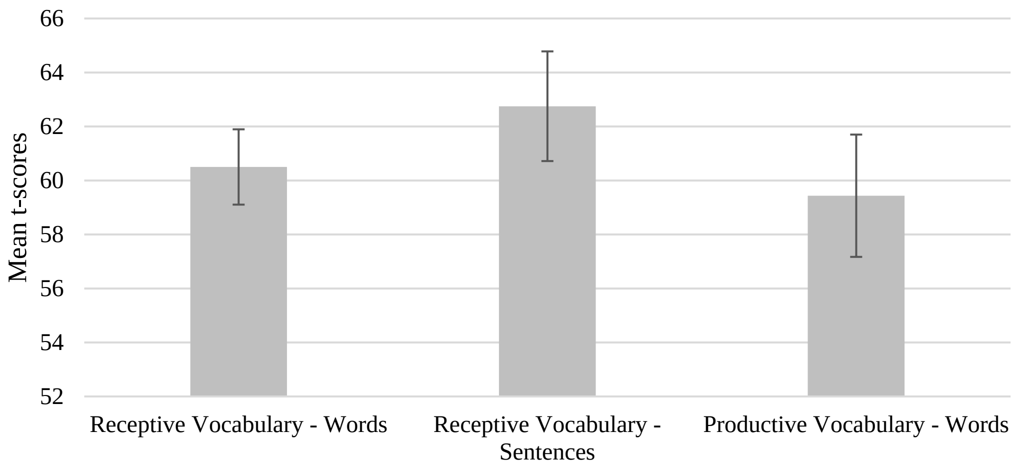

Figure 6-7. Mean T-Values and SE for SETK

Note: T score normative means are 50, SD=10.

6.4.3.1 Infant index-finger pointing predicting later language abilities.

The AoE of index-finger pointing was significantly correlated with productive vocabulary at 18 months ($r(31)=-.53$, $p=.002$) and at 26 months ($r(21)=-.56$, $p=.008$), as well as receptive vocabulary at 26 months ($r(21)=-.64$, $p=.002$). The same was true when using the binary variable whether infants were able to use the index-finger pointing gesture at 11 months (yes/no) to compare language abilities at 26 months. Both the productive and receptive vocabulary of infants at 26 months was significantly higher for infants who were able to use index-finger pointing gestures at 11 months (for the productive vocabulary $t(18)=-3.51$, $p=.003$ and receptive vocabulary $t(18)=-3.34$, $p=.004$). However the productive vocabulary at 18 months did not differ significantly ($t(29)=-1.22$, $p=.233$). When using Median splits to convert infants' language abilities into a binary variable, infants who were able to use the pointing gesture at 11 months were more likely to have a high receptive vocabulary at 26 months ($\varphi(20)=.4$ $p=.037$). There was no significant correlation between infants' productive vocabulary and infants' ability to use the index-finger pointing gesture at 11 months, neither at 18 nor at 26 months (for 18 months $\varphi(31)=.22$ $p=.112$, for 26 months $\varphi(20)=.31$ $p=.08$).

6.4.3.2 Interrelations between parental input, infant index-finger pointing and language.

To assess potential mediation effects, we ran correlation analyses using the earlier identified significant predictors of the AoE of index-finger pointing to see whether they would also significantly predict language abilities at 18 and 26 months.

As for the productive vocabulary at 18 months, the only significant predictors were caregivers' pointing gestures at home at 8 months ($r(32)=.39$, $p=.023$) as well as at 10 months ($r(32)=.3$, $p=.042$). None of the other predictors were significant (all $r<23$, all $p>.097$, all $\varphi<.21$ $p>.11$).

Due to the reduced sample size at 18 months, we re-analyzed the correlations between the AoE of index-finger pointing and the two significant predictors of the productive vocabulary at 18 months again with the reduced sample size of families who returned the FRAKIS questionnaires. Both predictors were still significant (all $r>.37$, all $p<.023$).

There were several significant predictors of infants' receptive vocabulary at 26 months. Both parental responsiveness during free play at 10 months ($r(21)=.48$, $p=.012$), as well as caregiver pointing at home at 10 months ($r(22)=.58$, $p=.002$) and the amount of triadic interaction at home at 10 months ($r(21)=.49$, $p=.019$) were significantly correlated with the receptive vocabulary. All other predictors of the AoE of index-finger pointing were not significant (all $r<.36$, all $p>.105$). As for the correlations using median splits, only caregiver pointing at home at 10 months was also a significant predictor of infants' receptive vocabulary at 26 months ($\varphi(22)=.36$ $p=.043$). A non-parametric partial correlation analysis was still significant when controlling for the inter-correlation with infants' ability to use the pointing gesture at 10 months (*rho(par)*= .57, *p*=.008).

There were no significant predictors of infants' productive vocabulary at 26 months (all $r<.25$, all $p>.068$, all $\varphi<.23$, $p>.074$).

We repeated the same controls for the reduced sample of those families that returned for testing at 26 months (N=22). All predictors of the AoE of index-finger pointing were still significant (all $r>.48$, all $p<.012$).

Next we ran mediation analyses to see whether the relation between parental input and infant language outcomes were mediated by infants' ability to use the index-finger pointing gesture. Due to the highly reduced sample size (N=19 for predicting the vocabulary at 26 months and N= 27 for predicting the vocabulary at 18 months) and the non-normal distribution of many predictors we included bootstrapping (5000 samples). In all cases, the bootstrapping controls meant that one of the necessary conditions for mediation was no longer met (meaning one of the predictions was no longer significant, since the confidence interval included 0). This was the case for parent pointing at home at 8 months and 10 months and all predictions regarding vocabulary at 26 months.

Partial correlation analyses, controlling for the inter-correlation with the AoE of index-finger pointing resulted in the correlation between parents' pointing gestures at home and infants' productive vocabulary at 18 months to no longer be significant (for parents' pointing gestures at home at 8 months $r(28)$=.12, p=.264, and at 10 months $r(28)$=.1, p=.29). As for infants' receptive vocabulary at 26 months, parental pointing at 10 months was still a significant predictor when controlling for the AoE of index-finger pointing ($r(18)$=.45, p=.024), while the amount of triadic interaction at home at 10 months and parental responsiveness during free play at 10 months were no longer significant (for triadic interaction $r(18)=.12$, $p=.306$), for responsiveness during free play $r(18)=.28$, $p=.12$).

6.4.3.3 Summary: Predicting vocabulary.

Infant index-finger pointing, both the AoE of index-finger pointing measured in the decorated room as well as infants' ability to use the index-finger pointing gesture at 11 months, were significantly correlated with later vocabulary at 18 and 26 months, both productive and receptive. Several of the predictors of the AoE of index-finger pointing at well as infants' ability to use the index-finger pointing gesture at 11 months were also significantly correlated with later language abilities (i.e. the frequency of caregivers' pointing gestures at home at 8 and 10 months, parental responsiveness during free play and the amount of triadic interaction at home at 10 months). Due to the reduced sample size for all language measures, mediation analyses were not possible. Partial correlations revealed that only parental pointing at home at 10 months was still a predictor for infants' receptive vocabulary at 26 months when controlling for the AoE of index-finger pointing (including the binary median split variables).

6.5 Discussion

The current study investigated how parents' and infants' deictic gesture use and interactions were distributed across settings, comparing lab based semi-structured observational measures (i.e. the decorated room and free play) to home observations, including a more diverse and representative sample of German and Turkish-German families.

Both parents and infants used index-finger pointing gestures earliest and most frequently in the decorated room. There were very few pointing gestures recorded during free play, showing this setting to be less suitable to measure infants' ability to use the index-finger pointing gesture as compared to the decorated room, which is on par with earlier research (Puccini et al., 2010).

The results on onset and frequency of infants' index-finger pointing gestures also closely mirror earlier results (Ruether Liszkowski submitted) showing the decorated room to be a reliable measure of competence. During the hour of recording at home we were able to record pointing from both infants and caregivers. Even though data was only collected at 8 and 10 months it seems likely that a similar level of competence would be found at home as it was in the decorated room. However, as a diagnostic tool, the decorated room seems to be more suitable, being a shorter and more standardized measure of competence.

As for other deictic gestures used by parents and infants, showing gestures were the most frequently used gestures both during free play and at home during the early months. By 12-18 months during free play recordings and at 18 months at home, there was a decrease in showing gestures from both parents and infants and an increase in pointing gestures. At home, pointing gestures were the most frequently used deictic gesture at 18 months, showing interaction overall becoming more distal. However, the increase in time spent reading books might also contribute to this.

While we did record showing gestures from parents and infants, both the age of onset as well as the overall frequency of showing gestures used differed to previous studies (Cameron-Faulkner et al., 2015). There are several possible explanations for this. First, in order to not artificially inflate gesture use, when a ritualistic play was initiated (i.e. rolling a ball back and forth, stacking a tower), we only coded the initiating gestures. Second, the toys selected for free play in this study might not have been best suited to elicit showing gestures. So far, there has been no systematic study on the influence of toy selection on gesture use during free play and often, the specific toys used are not even reported. There is some indication that certain aspects of toys, e.g. difficulty, complexity, familiarity might lead to differences in infants' (Gavrilov, Rotem, Ofek, &

Geva, 2012; Stoneman, Cantrell, & Hoover-Dempsey, 1983) and caregivers' (González, 1996; O'Brien & Nagle, 1987) behaviors. Caregivers have been shown to adapt their behaviors within free play settings according to the difficulty of the toys and their infants' competences (Kermani & Brenner, 2000). However, further studies are needed to ascertain a difference in gesture use due to different toy sets. A third influencing factor might be the order of testing. The free play session was always conducted at the very end of testing (usually testing lasted 30-50 minutes). Potentially this meant infants were fatigued, leading to less overall gesture use.

Comparing parents' and infants' gesture use across settings, we found very few correlations for parents' gesture use, meaning parents showed different patterns of behavior in the laboratory than they did at home, while infants' behaviors were much less influenced by the settings. The laboratory setting, with several cameras visible at all time, might make parents much more likely to exhibit what they consider socially desirable behaviors. While they were also aware of being observed at home, with an experimenter present in the room at all times, both the length of observation (i.e. one hour) as well as the familiar setting and the ability to continue with their daily routines should have led to more natural behavioral patterns leading to a more valid capture of infants' social interactional environments (Ahnert & Haßelbeck, 2014; Lamm et al., 2014). Another thing to consider is~~,~~ that the home environments also lead to some interactional frames that were not possible in our free play and decorated room settings, for example book reading, primary care and feeding, which are important sources of deictic gestures and referential input for infants at home and have been shown to contain setting specific referential activities (Kniskern et al., 1983).

Overall the laboratory sessions proved to be useful for faithfully eliciting specific gestures, for example, showing whether infants were capable of using pointing gestures. However, they also overestimate their frequency of use and in the case of parents also show different patterns of gesture use than at home. Infants under the age of two do not seem to significantly adapt their gesture use to any specific settings yet. However, in order to truly capture infant's socio-cultural environments, observing them at home, over larger periods of time is necessary.

A final interesting finding was a significant difference in deictic gesture use between German and Turkish-German parents, with Turkish-German parents using more deictic gestures both during free play and at home. This might be because Turkish-German parents were more susceptible to social expectations and more likely to exhibit behaviors they deemed socially desirable in a parent. While perceived social desirability of specific behaviors is well studied concerning things like self-report questionnaires (Dodou & Winter, 2014; Richman, Kiesler, Weisband, & Drasgow, 1999) there has been no systematic study on its effects on studying parent-infant interaction. Further studies are needed to disentangle the potential influence of perceived social desirability on parental behaviors in observational studies. Parents were left blind to the goals of the study and instructed to behave as if they were at home, but it is to be expected that being observed led to a greater amount of socially expected behaviors in both samples. It could be, that there is some difference in what parents of both cultural groups deemed socially desirable behaviors, though we found no significant differences in their cultural self-construal or socialization goals. Interestingly, for the home observations the difference in gestures was only apparent during the first visit at 8 months, suggesting parents behaviors were more similar once they got used to being observed at home, while the difference in the laboratory remained until the fifth session further increasing the importance of naturalistic home observations for capturing infants' socio-cultural environments.

The current study also expanded on earlier results on predictors of the age of emergence of infant index-finger pointing by including different types of deictic input (i.e. showing gestures, pointing gestures, overall triadic interaction) and earlier infant gestures (i.e. hand pointing gestures and showing gesture) replicating earlier findings (Rüther & Liszkowski, submitted) as well as expanding on them. We included both a measure of the age infants first used two index-finger points in one session of the decorated room (since this had been determined as the best setting to measure onset) as well as a more age-centered measure, diving the sample into infants who were considered pointer (i.e. 2 points per session) at 11 months and those infants who did not yet use the index-finger pointing gesture at 11 months (the median age of onset of index-finger pointing) trying to understand which factors influence infants to be considered early index-finger pointers.

We found several significant predictors for the AoE of index-finger pointing. The earliest predictors were the frequency of parental pointing at home as well as parents' referential uptake of their infants' hand pointing gestures in the decorated room, similar to findings by Ger et al. (2018) though they found a significant correlation at 10 months predicting later frequency of use, not the age of onset of pointing. While we were not able to directly replicate our earlier findings, we found an influence of parental pointing in the decorated room at 9 and 10 months (however, after a partial correlation analysis, only parental pointing at 10 months was still a significant predictor). We were not able to replicate earlier results on the importance of infant showing gestures (Cameron-Faulkner et al., 2015), though as mentioned above it is possible the current study did not adequately capture infants' use of showing gestures. Though the overall frequency of hand pointing gestures was not significantly correlated with the AoE of index-finger pointing, using median splits, infant hand pointing at 8 months was significantly correlated with infants being able to use the pointing gesture at 11 months (controlling for the amount of referential uptake form parents).

While we were able to identify further significant predictors at 10 months (the amount of triadic interaction, caregiver pointing and showing gestures at home at 10 months as well as caregiver showing gestures during free play), the amount of triadic interaction at home as well as the amount of caregiver pointing at home were significantly higher for infants already using index-finger pointing gestures and no longer significant when only including infants who were not yet able to use the index-finger pointing gesture, suggesting that the correlations found were due to parents increasing their deictic input in reaction to infants' emerging index-finger pointing gestures. Similarly, caregiver showing gestures at 10 months at home and in the laboratory were no longer significantly correlated with the AoE of index-finger pointing when only including infants who did not yet use index-finger pointing gestures at 10 months. However, since this also highly reduced the sample size (in some cases to less than 20 infants) the lack of significance might be due to the size of the effect and further study is needed.

In addition to infants' hand pointing gestures at 8 months, the only other significant predictor for infants' use of index-finger pointing gestures at 11 months, after control analyses, was caregiver responsiveness during free play at 10 months, meaning infants of parents who had a high proportion of deictic gestures aimed at objects infants were focusing on were also more likely to be index-finger pointer at 11 months. Caregiver pointing and caregiver referential uptake at 8 months were no longer significant after partial correlation analyses. Caregiver pointing, caregiver showing gestures and triadic interaction at home at 10 months as well as parents' referential uptake at 10 months and parents' showing gestures during free play at 10 months were no longer significant when excluding infants who were already able to use the index-finger pointing gesture at 10 months and were also significantly correlated with infant index-finger pointing at 10 months, meaning infants of parents who used above median frequencies of gestures were more likely to already use the index-finger pointing gesture at 10 months.

The results indicate that early parental input is important for infants' development of index-finger pointing. While the correlations with the frequency of parental pointing potentially speak to the theory of parental modeling, the importance of referential uptake of infants early hand pointing gestures indicate that it is not simply the modeling of the gesture that is important but parents' reacting to their infants early gestural attempts and shaping them into the more conventional form of index-finger pointing. This is in line with research showing that infant pointing is often aimed at eliciting a referential response from their caregivers (Liszkowski et al., 2004). Importantly, the results presented here show that even at 8 months old, referential uptake of their own gestures is relevant to infants' gestural development. It seems that, before infants themselves are able to use the index-finger pointing, or even reliably follow a pointing gesture, their parents points, especially those aimed at objects infants themselves had previously pointed at using hand pointing gestures already have an impact on their communicative development. It would follow that if referential uptake of these early gestures is reflected in their development, infants already have some referential intention when using these gestures. Infants own early attempts at communication, using the whole-hand to point at objects were also correlated with their later ability to use the index-finger pointing gesture, when controlling for the proportion of parental responses to their points indicate that there are also intra-individual cognitive components that predict the development of index-finger pointing, which is similar to earlier results (Rüther & Liszkowski, submitted). While the very origin of infant pointing is still unclear, recent results point to pointing developing from early object exploration (O'Madagain et al., 2019).

Once infants start using the index-finger pointing gesture caregivers seem to increase and adapt their gestural input in accordance to their infants' abilities, making the early gestural development of infants a highly collaborative process (Renzi et al., 2017). The results presented here point to the importance of social-interactional experiences in the development of social-cognitive abilities (Carpendale & Carpendale, 2010) as well as underlying social-cognitive processes which make participating in social interaction possible (Tomasello, 2007). The current results do not only add further longitudinal evidence to the influence of the social-interactional environment of infants on their development of index-finger pointing, they also replicated earlier results using a more diverse and representative sample that included families with a Turkish migration background. Further we were able to show that parental pointing, recorded at home in their natural environment was also a significant predictor of the AoE of index-finger pointing, expanding on earlier results using the decorated room paradigm, which overestimates parents' use of the index-finger pointing gesture.

Lastly, the current study replicated earlier findings on the influence of infant index-finger pointing on their later language abilities as well as the interrelatedness of parent input, infant pointing and language. We were able to show that both infants' age of onset of index-finger pointing as well as their ability to use the index-finger pointing gesture at 11 months (median age of onset) was significantly correlated to later language abilities, both the productive vocabulary at 18 and 26 months as well as the receptive vocabulary at 26 months, including a small sub-sample of bilingual infants at 18 months. This replicated many earlier studies on the importance pf infants index-finger pointing in predicting later language abilities (Colonnesi et al., 2010). There were also several predictors of infants' index-finger pointing that were correlated to infants' language abilities. The frequency of parental pointing at 8 and 10 months at home was significantly correlated with infants' productive vocabulary at 18 months and parental responsiveness during free play as well as the amount of triadic interaction at home and the frequency of parental pointing at home at 10 months was significantly correlated with infants' receptive vocabulary at 26 months. We found no significant predictors for productive vocabulary at 26 months that were also correlated with infants' index-finger pointing. Due to the reduced sample sizes and non-normal distributions, mediation analyses were not possible. However, partial correlation analyses, including the inter-correlations between the significant predictors of later language abilities and infant index-finger pointing (i.e. the AoE of index-finger pointing and infants' ability to use the pointing gesture at 11 months respectively) meant that only caregiver pointing at home at 10 months was still a significant predictor for both the productive vocabulary at 18 months as well as the receptive vocabulary at 26 months. These results indicate that at least some of the reported predictors of language abilities might actually be predictors of index-finger pointing, while some parental input, in this case specifically parental pointing, is important for language development. This is not unexpected as points are often accompanied by labels for the referred objects, and have been shown to help infants map the spoken words to objects or actions (Goldin-Meadow & Alibali, 2013; Igualada, 2014; Tomasello & Todd, 1983).

There were some limitations to the data presented here. First, the Turkish-German sample was highly diverse (including both first and second generation immigrant mothers and fathers as well as infants growing up monolingual and bilingual to varying degrees) and significantly smaller than the non-migrant sample, making further sub-group analyses, especially on infants' language development difficult. Also, the data set for infants' language abilities was comparatively small. Further studies should include a larger migrant sample, potentially also sampling different migrant communities and control more stringently for bilingualism. Second, while deictic gestures are an important part of infants social-interactional environment, a more fine grained analysis of input, including parents' vocalizations, and in the case of the decorated room movements (see Ger et al., 2018) should be included in future studies in order to better qualify caregiver input. Third, while the hour-long recordings at home proved to be an important measure of infants' socio-cultural environments, even hour long video at home might skew results. (Bergelson, Amatuni, Dailey, Koorathota, & Tor, 2019) were able to show that input during one hour of video is not necessarily representative of overall input. A potential solution might be spot observations, shorter times of recording, spaced over several different times of day and days of the week in order to capture an even more representative picture of infants interactional environments, which has been shown to be effective in cross-cultural research (Abels et al., 2005; LeVine et al., 1996; Rogoff, 1978).

From an applied perspective, the results point to the importance of early intervention when targeting infants' communicative development, potentially already during the first year of life. While an earlier training study showed no effect on infant index-finger pointing (Matthews et al., 2012), our results indicate that interventions should target parents before infants are able to point and try to increase parents relevant responses to infants deictic gestures. All things considered, the results reveal that from very early on, infants' social-cognitive development is influenced by their social-interactional environment, with communicative input, infants' own gestural abilities and their language development being ontogenetically intertwined. While infants' early deictic gestures provide the foundation for oral linguistic communication (Colonnesi et al., 2010; Goldin-Meadow, 2007) their development is a product of social-interactional experiences.

7. GENERAL DISCUSSION

The main focus of this thesis was to trace the development of abilities central to cultural learning, namely gestural communication in the form of index-finger pointing as well as infants‘ understanding of a referential pointing gesture and early language development, and ascertain whether the socio-cultural environment, in the form of caregiver interactions, influences the onset and development of these abilities. To this end, I analyzed longitudinal data, measuring infants‘ communicative competence as well as recording the frequency and quality of caregiver interactional input.

7.1 Summary of findings

Chapters 1-3 covered the theoretical and methodological background. Chapter 4 focused on the emergence of point comprehension to occluded objects, using a well-established paradigm by Behne et al. (2005) as a measure of preverbal referential understanding. Infants were tested monthly from 10 to 13 months on their ability to find a hidden toy using the experimenters’ index-finger pointing gesture. In addition, infants and parents were observed in a point elicitation paradigm, to measure infants’ own competence, using the index-finger pointing gesture, as well as parental use of the gesture, as a measure of infants’ social interactional experience. The results showed that instead of a sudden onset of the ability to understand a referential pointing gesture, it develops gradually from 10 to 13 months, with stable competence only emerging around 12-13 months. Further, infants’ own use of the index-finger pointing gesture was both concurrently related to infants’ point comprehension at 12 months as well as predictive of point comprehension (index-finger pointing at 11 months was correlated to point comprehension at 12 months). Similarly, parent pointing was longitudinally predictive of point comprehension. Instead of referential understanding being causal to the emergence of index-finger pointing, it seems to emerge through social-interactional experiences, a first indication of the influence of the social-interactional environment on cognitive development during infants' first year of life. In contrast to previous accounts (Carpendale et al., 2013), the current results clearly shift the emergence of cognitive referential skills to the beginning of infants' first year of life. However, contrary to previous findings (Csibra & Volein, 2008), which would have suggested infants already showing a clear competence at 10 months (indicated by above chance search performance), the picture here is one of a developing ability well across infants' second year of life. This view is consistent with findings by Behne et al. (2005) who showed an increase in individual level competence as late as 18 to 24 months of age.

Chapter 5 focused on the emergence of index-finger pointing testing several potential predictors, both intra-individual cognitive and motor precursors to index-finger pointing like infants' use of showing and whole-hand pointing gestures, as well as their ability to follow a simple pointing gesture, and parental pointing, as a measure of infants' social-interactional input. Again, data sampling was longitudinal with monthly data collection from 8 to 13 months. The chapter included a second, cross sectional data set on parental pointing of infants aged 5 and 7 months, using the same point elicitation measure implemented in the prior studies. Concurrent correlation analyses, once all abilities had emerged, suggested a common capacity of communication including showing gestures, infant index-finger pointing and point following, excluding infants' use of the whole-hand pointing gesture. Predicting the onset of index-finger pointing, point following, and whole-hand gestures as well as parental pointing were found to be significant predictors, with regression analyses pointing to a particular importance of parental pointing. Overall, the results point to a combination model in predicting the ontogeny of index-finger pointing. The results further underline the influence of social-interactional experiences on communicative development during the first year of life, while also indicating some intra-individual determinants.

Chapter 6 expanded on the results of chapter five, measuring and comparing social-interactional input in different settings from 8 to 18 months, both semi-structured lab based measures of social interaction, as well as naturalistic home observations. Data collection also included infants' early language abilities at 18 and 26 months. The study replicated earlier results from chapter 5 on the importance of parental pointing on the emergence of index-finger pointing, in both a structured point elicitation paradigm, as well as using data from home observations. Further, results showed that not only parental pointing itself, but also referential uptake of infants' points themselves (when infants were 8 months old), was predictive of the age of onset of index-finger pointing, similar to results from Ger at al. (2018), indicating some referential intentions in infants' own early communicative attempts. The study also replicated and expanded on earlier results on the importance of infants' ability to use the index-finger pointing gesture for language development (R. Brooks & Meltzoff, 2008; Butterworth & Morissette, 1996; Lüke et al., 2016; Lüke et al., 2017), while also showing that parental input, in the form of parental pointing, was still predictive after controlling for its correlation with the age of index-finger pointing (Cartmill, Pruden, Levine, Goldin-Meadow, & Center, 2010).

In addition, chapter six further illuminated the longitudinal relatedness of caregiver and infant gesture use, showing an increase in caregiver input, due to an increase in infants' communicative abilities, namely their ability to use the index-finger pointing gesture. This is similar to results from chapter 5 showing a significant difference between the frequencies of pointing gestures used for parents of 5-6 months old infants compared to the older sample.

The following paragraphs will discuss the results in the context of the broader developmental theories presented in the introduction.

7.2 Social-interactional predictors of cultural learning

Chapter 1 presented evidence on the universality of pointing, referential understanding and language (Liszkowski et al., 2012). Further, I presented evidence from non-human primates showing them unable to use and understand pointing and language as we do (Tomasello et al., 1997; van der Goot, Marloes H. et al., 2014; Vauclair & Meguerditchian, 2008; Vilain et al., 2011). All of this speaks to the presence of an evolutionary component in the ontogeny of communication. However, even if there is an evolutionary competent with some innate biological foundation, its emergence might still be dependent on interactional experiences and based on developmental precursors. In fact, the results presented here as well as in chapter 1 would suggest that infant learning is influenced by interactional experience from the very beginning, and that in turn infant maturation and development also influences the type of input infants receive (Deák, Krasno, Jasso, & Triesch, 2017; Renzi et al., 2017). The reason that these abilities develop at similar time points (Carpenter et al., 1998) might be due to aspects of brain maturation but does not mean they can develop without interactional experience. Starting from the mainly dyadic state during their first few months of life, infants learn, through interaction, to understand that others have intentions similar to their own, as well as a motivation and willingness to share them (Tomasello, 2008). Understanding that these intentions are communicated as well as communicating their own intentions is the very basis of cultural learning and can only develop through interactional experience.

All three empirical chapters presented evidence on the influence of social-interactional experience on the onset and development of both index-finger pointing as well as referential point comprehension, speaking to a social-cognitive account of referential preverbal communication (Liszkowski, 2018). Both Chapter 3 and 4 showed that the frequency of parental index-finger pointing in the decorated room was predictive of an increase in point comprehension and of the AoE of index-finger pointing. So far, no study was able to show the onset of index-finger pointing varying as a function of paternal rates of pointing. However, in both cases, intraindividual predictors on the child level were also present, suggesting a combination model of both socialization and intra-individual factors in the ontogeny of these two abilities.

In the case of point comprehension infant index-finger pointing itself was also both predictively and concurrently correlated. This would suggest that through both following other's directing gestures as well as using their own gestures to direct attention infants build up cognitive referential expectations about others' communicative behaviors which in time start to extend to non-perceivable referents.

In the case of the onset of infant index-finger pointing, whole-hand pointing and point following were significant intraindividual predictors. While infant showing gestures were initially predictive replicating earlier results (Cameron-Faulkner et al., 2015), when tested against all other predictors using regression analyses they failed to explain any unique variance.

Infant point following had previously been identified by a training study by Matthews et al. (2012). The study by Matthews et al. included a training design, where infants and parents were tested several times over the course of one month (either at 9, 10 or 11 months) and parents were instructed to spend 15 minutes a day on an activity that would increase pointing frequency. In their study the training did not increase the likelihood that infants were considered pointer at the end of the one month period. They took the results to mean that rather than the behavior being socialized, infants' social cognitive development determined the onset of pointing. While the results also point to intraindividual factors of maturation, they also suggest that this one-month period might not have been enough to show an influence of socialization, in fact, the critical time point seems to be before infants themselves actually start to use pointing gestures, at 8 months.

Interestingly, in the study presented in chapter 5, neither point following nor whole-hand pointing were predicted by parental pointing. Point following, not referential point comprehension, might simply reflect a more general skill of attention following that rests on skills of individual cognition, which would be in line with studies on early attentional priming effects (Farroni, Massaccesi, Pividori, & Johnson, 2004; Grossmann, Johnson, Farroni, & Csibra, 2007) and results from non-human primates, who are also able to follow others' attention (Emery, Lorincz, Perrett, Oram, & Baker, 1997; Tomasello, Hare, Lehmann, & Call, 2007). However, some researchers posit that gaze following might actually be a result of infants' observations of their parents handling objects (Deák et al., 2014). They observed infants aged 3-11 months with their parents, in naturalistic settings, and found evidence for positive reinforcement learning that might explain the development of gaze following. However, both the cross sectional design, as well as the small sample sizes within the age groups make these results preliminary at best. Longitudinal as well training designs would be needed to support the proposed learning mechanisms.

Since whole-hand pointing was also not predicted by parental pointing, it does not seem to be a simple imitation of earlier parental behaviors, since adults do not use the whole-hand to indicate objects, but potentially hand pointing reflects some simpler bodily form of relating to an object, which emanates from infants' individual activity, which is in line with recent results on pointing potentially emerging from object exploration (O'Madagain et al., 2019).

Chapter 6, using a more diverse, representative sample including families with a migration background, gave further evidence of the influence of socialization. Caregiver pointing at home at

8 months and at 10 months in the decorated room, as well as caregiver referential uptake of infants' early whole-hand pointing gestures in the decorated room at 8 months, were significantly correlated with the age of emergence of index-finger pointing. Further, parents' deictic gestures aimed at objects infants were focusing on during free play at 10 months were also a significant predictor, not their own use of showing gestures. While we did not directly replicate the results from chapter 5 on infant hand pointing gestures, when using median splits, infants who used frequent whole-hand pointing gestures at 8 months were more likely to use the index-finger pointing gesture at 11 months.

One question that remained from chapter 5 was whether parental pointing in the decorated room constitutes an adequate measure of social-interactional input. The context of regard created in the decorated room (Puccini et al., 2010), by prohibiting touching the objects, while very likely to induce pointing behaviors, might not necessarily be very prevalent in infants' lives and has been shown to differ across individuals and settings (Salomo & Liszkowski, 2013). Data collected with the decorated room paradigm might thus not necessarily reflect the natural rate of parent-infant pointing interactions. However, parent pointing at home at 8 months was a significant predictor of the age of emergence of index-finger pointing, validating results from the decorated room by measuring parental input in a more naturalistic setting. Importantly, parents' use of showing and giving gestures was not a significant predictor of infant index-finger pointing, though showing gestures were more frequent for parents of infants who were already using index-finger pointing gestures at 10 months.

Interestingly, the frequency of parental points in the decorated room at 8 months was not significantly correlated, instead the correlation was found at 10 months. However, the proportion of parental gestures aimed at objects infants had previously pointed at using whole-hand gestures were. Ger et al. (2018) found similar results at 10 months predicting later frequency of index-finger pointing. Potentially infants' earlier gestures themselves might not necessarily be important predictors rather, parents' reactions to these gestures might be the, particularly if their gestures are relevant responses to infant gestures. Our prediction at 8 months, of parents referential uptake of infants' pointing gestures is interesting in a second way, at that age infants should not yet be able to fully understand the referential content of parents' gestures (see results from Chapter 4), however, since the parental uptake of their gestures is relevant to the development of index-finger gestures, they must already have some (although potentially rudimentary) referential intentions when they are pointing themselves, though more research is needed to understand to what extent.

Lastly, parental pointing at home was also predictive of infants' later vocabulary, even when controlling for its intercorrelation with the AoE of index-finger pointing, this is in line with earlier research on the importance of parent gesture for infants' language development (Iverson et al., 2008; Pan et al., 2005).

Overall the results from chapter 6 further underline the importance of parental input while also emphasizing that frequency of use itself might not be as important as gestures that are complementary to infants' own attentional frame and referential intentions.

The picture that emerges from the results of chapters 4-6 is one that fits most closely with social-constructivist accounts (Carpendale & Lewis, 2006; Heyes, 2012; Liszkowski, 2018; Moore & Barresi, 2017; Vygotskiĭ, 1978; Werner & Kaplan, 1963). Infants' social-interactional environment clearly influences the development of referential point comprehension, index-finger pointing and language, but there was also some evidence of intraindividual precursors to development. Importantly, parental referential uptake and responsiveness were as important as the overall frequency and type of gestural input.

What are the mechanisms that underlie this importance of early socialization? There have been some recent theoretical perspectives on the development of social understanding surrounding the so-called "second person information", that try to explain the importance of interaction to social-cognitive development. Instead of so-called third person information (i.e. observing someone) the second person information, meaning information about the interdependence of both interaction partners' activities, is gleaned through directly engaging others. Through experiencing second-person engagement infants gain understanding about themselves and others as intentional agents, and it is this information, which is crucial to social learning and at the very core of what we call joint or shared interaction (Moore & Barresi, 2017; Siposova & Carpenter, 2019). One of the necessary components for shared interaction to occur is communication, both interaction partners communicate their jointness, usually though mutual gaze or gestures (Siposova & Carpenter, 2019). Jartó et al. (2019) presented empirical evidence for the importance of second person information by comparing infants social-cognitive abilities using interaction based experiments as well as eye tracking experiments in a longitudinal study. Infants showed competencies earlier in the interaction based measures than eye tracking measure, showing that interactional information aides in early social-cognitive understanding.

Contrary to social-cognitivist accounts (Chomsky, 1988; Csibra, 2010; Fodor, 1981; Mundy & Newell, 2007; Spelke & Kinzler, 2007), even though infants were not yet able to fully understand referential intentions or the index-finger pointing gesture or even faithfully follow a simple pointing gesture, parents' use of index-finger pointing and the referential uptake of infants' very early pointing gestures were important predictors of later development. Further, both referential point comprehension as well as index-finger pointing emerged gradually, and we saw an increase in competence across months. The results also did not indicate that simple imitation or reinforcement learning would be enough to develop referential understanding or index-finger pointing as some accounts would expect (Deák et al., 2014).

7.3 Developmental interrelatedness of infant development and caregiver input

The results presented in chapter 5 and 6 also contained evidence of a reverse relationship to the one presented above, namely that infants' continued communicative development in turn influences the way their caregivers interact with them.

In the cross-sectional study conducted with parents and their infants aged either 5 or 7 months, we found a significant difference in the frequency of caregiver points for their infants, with caregivers of 7 months old infants using significantly more pointing gestures than parents of the younger sample. Around 6-8 months infants start to orient towards objects (around 6 months if the object is directly in front of the infant) (Striano & Bertin, 2005) as well starting to reach for objects (Brown, 2011) in turn caregivers often react in relation to this, for example by manipulating the object infants were focusing on (Deák et al., 2017). Potentially, parents notice this more active coordination of attention and start to indicate objects that are further away.

The results in Chapter 6 showed that parents increased the frequency of gesture use (both showing/giving gestures as well as pointing gestures) at 10 months due to the onset of index-finger pointing. We also recorded an increase in triadic interaction at home that was related to infants' use of the index-finger pointing gesture. We know that once infants use the index-finger pointing gesture the frequency of their caregivers' points are concurrently correlated (Liszkowski et al., 2012; Matthews et al., 2012). Barbaro et al. (2013) also showed caregivers adapting their behaviors in accordance with infants' sensorimotor skills, initiating increasingly elaborate social exchanges (like give and take) when infants were 6-12 months old. In fact, when infants start reaching for objects around 8 months of age, parents will react to this, usually by offering an object. In turn infants start to expect others to help them obtain objects that are out of their reach as evidenced by findings that they are more likely to reach for objects when someone else is present (Ramenzoni & Liszkowski, 2016). It seems, caregivers are sensitive to their infants' development and act accordingly. Infants' social-cognitive development is thus continually scaffolded by caregivers' expanding social actions in reaction to their infants' development. This means, social-cognitive abilities develop gradually and do not suddenly emerge due to maturation processes but are a result of infants' interactional experiences and in turn form the basis for further development (Barbaro, Johnson, Forster, & Deák, 2016; Deák et al., 2017; Renzi et al., 2017). This interdependence between infant development and caregiver behavior is most likely not restricted to the ages measured here but potentially begins even before birth and reaches much further into development.

7.4 Shared reference and shared intentionality

Both chapter 3 and 4 found meaningful concurrent correlations between infant index-finger pointing and other pre verbal communicative abilities, in both cases whole-hand pointing was not concurrently correlated with any of the abilities. Chapter 3 showed a synchronous correlation between referential point comprehension and index-finger pointing at 12 months, reproducing earlier findings (Behne et al., 2012; Liszkowski & Tomasello, 2011). In chapter 4 infant index-finger pointing, infant showing and giving gestures, as well as infants' ability to follow a simple pointing gesture to a lateral target were all concurrently intercorrelated at 11 months similar to results from Carpenter et al. (1998).

While the individual ages of onset for all of these different abilities covered ranges of several months (from 9/10-14 months), starting with showing/giving gestures and simple point following, around the time of the median age of onset of index-finger-pointing they start to be related to each other. Most likely this concurrence of abilities marks the emergence of joint, or shared reference. Meaning, starting around their first birthday, infants engage intentionally in diverse communicative activities with a general understanding of shared reference (Liszkowski, 2018). This goes beyond knowing what others perceive and reacting to this but knowing that others have intentions and are referring to entities and this can be shared. This unified ability around infants' first birthday, that is at the core of triadic interaction is also often called "shared intentionality" (Tomasello, 2008; Tomasello & Carpenter, 2007) or "other-mindedness", a basic understanding that others also have intentions similar to infants' own intentions, one of the most important skills in social cognition (Siposova & Carpenter, 2019) and gives infants the ability to use and understand language. However, since we found socialization influencing both index-finger pointing as well as referential point comprehension, can this convergence of abilities be found across different cultural communities? Both studies by Brown (2011) on the emergence of joint attention in non-industrialized communities as well as results from Salomo & Liszkowski (2013) would indicate this might not be the case. However, further systematic cross-cultural research is needed.

7.5 The case of whole-hand pointing

Throughout all three empirical chapters, whole-hand pointing was shown to be distinct from other deictic gestures. Historically, whole-hand pointing has not been considered a pointing gesture but rather a form of reaching (Leavens & Hopkins, 1999; O'Neill, 1996). However, newer studies, especially those using the decorated room paradigm (Cochet & Vauclair, 2010; Grünloh & Liszkowski, 2015; Liszkowski & Tomasello, 2011) showed whole-hand pointing to be clearly distinguishable from reaching gestures (through both arm extension and overall body posture). As a pointing gesture it usually precedes index-finger pointing while also co-occurring with index-finger pointing. It is also a gesture shared with non-human primates (Leavens & Hopkins, 1999).

In chapter 4, a low performance in point comprehension was correlated with a high frequency in whole-hand pointing gestures one month later. While whole-hand pointing was predictive of the onset of index-finger pointing in chapter 5 and to some extent in the study presented in chapter 6, it was not concurrently correlated with other deictic gestures like giving and showing gestures, point following and index-finger pointing at 11 months (when all abilities had emerged). Though not reported here due to the scope of the thesis, we were also able to replicate the negative correlation between whole-hand pointing and later language abilities found by Lüke et al. (2016). Overall the results would suggest, that while an early development of whole-hand pointing is an indicator of accelerated communicative development, the change from whole-hand pointing to index-finger pointing is an important landmark in the emergence of intentional referential communication (Liszkowski, 2018; Liszkowski & Tomasello, 2011) and a delay in the development of index-finger pointing as evidenced by the continued use of the whole-hand pointing gesture is an indicator of a lack of shared reference understanding.

7.6 Studying social interactions – methodological concerns

There are many possible ways to characterize and differentiate different socio-cultural environments (Parke, 2013a). The first two studies presented here were focused on semi-structured, lab-based assessments, i.e. the decorated room procedure and free play settings to assess infant competence as well as parental input. Chapter 6 expanded on these methods to include a more naturalistic approach of recording caregiver-infant interaction at home over a longer period of time without any instruction to the caregiver. In all three studies, the main focus was on parents' and infants' deictic gesture use, since the focus of the thesis was studying the ontogeny and development of communicative abilities in infants, and their potential predictors.

Through all three chapters, the decorated room procedure, a semi structured interactional format introduced by Liszkowski & Tomasello (2011) proved to be a reliable diagnostic tool for infants' ability to use pointing gesture, as well as an important measure of parental pointing and referential uptake of infants' pointing gestures, both of which were important predictors of infant index-finger pointing. It is noteworthy that only 5 minutes of observation were able to capture infants' pointing development. When comparing the onsets of index-finger pointing in chapter 6 in the decorated room and at home, no infant used the index-finger pointing gesture earlier at home than in the decorated room (though data on infant pointing at home at 9 months was not collected).

However, chapter six revealed important methodological concerns. When comparing caregiver input from the different settings, there were differences in their behavioral patterns, in contrast to infants, who did not yet adapt their interactional patterns to the different settings provided. This is in line with earlier, cross-cultural research by Lamm et al. (2014). While the lab-based assessments proved best at faithfully eliciting specific behaviors, they overestimated the frequency of gestures used as well as revealing different behavioral patterns. There are several potential sources for these qualitative as well as quantitative differences.

First, laboratory measures might be more vulnerable to effects of social desirability when comparing them to naturalistic observations at home (Lamm et al., 2014). While some influence at home cannot be discounted, it would be expected that parents display behaviors they deem socially desirable, the presence of familiar objects and routines, as well as a long recording time should lead to a more valid measure of interactional input.

Second, considering the large differences in showing gestures used between chapter five and six, both of which recorded caregiver-infant dyads for five minutes interacting with a set of toys, shows that especially when only recording short amounts of time, settings like the free play procedure are most likely vulnerable to issues like toy selection as well as fatigue effects due to prior testing. While there is no systematic study of the influence of different features of toys (i.e. difficulty, familiarity etc.), there are indications that both infants' (Gavrilov et al., 2012; Stoneman et al., 1983) as well as caregivers' (González, 1996; O'Brien & Nagle, 1987) behaviors are impacted by different toy features. Some features of the laboratory might also overestimate socio-cultural differences i.e. influence cultural groups differently in relation to parents' familiarity with research facilities (see differences in Chapter 6). Potentially, lower SES samples might also be more likely to change their behaviors in unfamiliar laboratory settings further indicating the necessity to include naturalistic observations in socio-cultural research.

Infants' physical world during their first year of life is socially mediated by their caregivers, they introduce new objects and learning experiences (Parke, 2013b). Infants slowly start to gain independence towards the end of their first year of life and begin seeking out learning environments. Closely documenting those exact environments, instead of simply documenting their reaction to specific objects in the laboratory is important to fully understand the mechanisms involved in infants' social-cognitive development.

Considering all this, future studies focusing on the social-interactional environment of infants should include a mixed-methods approach, combining naturalistic observations as well as structured assessments of competence. In light of the increasing challenge of non-replications in developmental research, as well as considering the varied challenges of socio-cultural studies, researchers need to closely document all of the parameters involved in their observations of caregiver infant interaction as well as conducting further systematic study of the influencing parameters.

7.7 Limitations and Implications for future research

There were some specific limitations to the different studies covered in the previous chapters that were already discussed within each chapter. One major difficulty in longitudinal and cross-cultural research is the question of recruitment and sample sizes. Monthly data collection over larger periods of time as well as home observations, while important to truly trace the development of social-cognitive abilities usually lead to smaller sample sizes, make data loss due to drop outs more likely as well as potentially leading to selective sampling, especially when trying to sample non WEIRD groups (Henrich, Heine, & Norenzayan, 2010a). In turn, when collecting naturalistic interactional data, this usually involves a large amount of video data that needs to be coded and analyzed making data collection very costly in several regards. In our case, some more complex analyses were not possible with the samples we collected. However, despite the comparably low power (when compared to cross sectional studies, which is why they far outnumber longitudinal designs in developmental research) we were still able to find meaningful longitudinal correlations, using several different methods (i.e. median split analyses, Monte Carlo permutation tests, partial correlations and multiple regression analyses) to confirm the different models. We were also able to replicate some of the exploratory findings from chapter 5 in chapter 6 adding further weight to the results.

One potential answer to the problem of small sample sizes in longitudinal studies is collecting data across different laboratories with a large number of collaborating researchers, like the “ManyBabies” project (see Frank et al., 2017), who are working on the replicability of central developmental measures and abilities like implicit Theory of Mind. Training studies are also needed to confirm some of the results presented here.

While data collection started before the so-far reported onset of index-finger pointing and referential point comprehension to capture their development, some questions still remained about potential predictors. Future studies should include even earlier data collection, potentially starting around the time when infants are starting to interact with objects around 3-4 months of age. In all three chapters, caregiver gestural input was used to measure infants social-interactional environment, while this can be a good proxy for overall input, including caregiver vocalizations as well as a more dynamic measure of interaction in the form of gestural conversational chains (see Boundy et al., 2016; Cameron-Faulkner et al., 2015) might be promising.

One important aspect to parent-infant interactions and in fact human interactions as a whole was not analyzed as part of the studies presented here, which is affect. Affective engagement is important to maintain interactions (Moore & Barresi, 2017) and a crucial form of feedback for infants (Legerstee, Markova, & Fisher, 2007). Affective feedback is a crucial part of dyadic interactions during the early months of infant development (Landry, Smith, Miller-Loncar, & Swank, 1998). Positive caregiver affect during infants' first months of life has been linked to cognitive (Sheinkopf et al., 2016) and language development (Steelman, Assel, Swank, Smith, & Landry, 2002). Positive caregiver emotional reactions might be a source of positive reinforcement, increasing infants' desire to engage in interaction thus providing learning opportunities. Including information about caregiver affect and affective attunement during interactions with their infants might help us further understand the mechanisms underlying early social-cognition.

Future studies should further include even more culturally diverse samples to see whether the associations reported here are culturally universal, in order to further understand the mechanisms involved in the development of cultural learning skills. While there are promising cross-cultural studies on imitation (Clegg & Legare, 2016; Legare & Nielsen, 2015) as well as triadic object exploration and joint attention (Little et al., 2016; Salomo & Liszkowski, 2013), index-finger pointing (Lieven & Stoll, 2013; Salomo & Liszkowski, 2013), more comprehensive studies comparing caregiver input as well as the interrelations between different social-cognitive skills across a wider variety of cultural contexts are needed.

7.8 Concluding remarks

What makes humans unique is our capacity of learning from each other in highly complex ways, our so-called ability for cultural learning. At the heart of this is our ability to understand and share others' intentions and communicate about them in complex ways, through gesture and language.

All three empirical chapters of this thesis provided evidence that the social-interactional environment of infants, in the form of caregiver interaction has a profound influence on the onset and development of key abilities necessary for language development and cultural learning. However, this relationship between infant development and caregiver interaction is not unidirectional but both are intertwined from the very beginning with infants' emerging abilities informing caregiver interaction and caregiver interaction in turn shaping infants' development across ontogenetic time (Renzi et al., 2017; Vygotskiĭ, 1978). From an applied perspective, these results speak to the importance of early intervention when targeting infants' social cognitive and language development.

I was able to show that abilities develop gradually over time, for example early whole-hand pointing already entails some form of intentional relation to referents however, across the following months, as infants learn to use pointing gestures more flexibly and gain further understanding of others' intentions: Around infants' first birthday it has developed into a rich communicative understanding that enables infants to fully participate in shared intentionality

(Liszkowski, 2018) and together with parental input forms the basis of language acquisition. Similarly, with referential point comprehension, infants already exhibit some skill at 10 months however, it is only months later that a stable understanding of others' referential pointing gestures truly emerges.

The results presented here also revealed more about the mechanisms involved in the ontogeny of cultural learning skills. Neither simple imitation, reinforcement learning nor developmental maturation itself is enough for these abilities to emerge, infants need interactional experience in the form of relevant caregiver scaffolding, which continually develops infants' understanding of shared referentiality.

Further, the preceding chapters revealed that it is important to consider how we sample caregiver-infant interactions. While there is no one perfect method to investigate the interplay between the social interactional environment and infants' social cognitive development and any data-gathering method will effect participants' behavior, converging results from different methods (i.e. naturalistic interaction sampling, semi-naturalistic and experimental measures) can give us some confidence in their results. There is still much to uncover about the influence of social-interactional experience on infants' social cognitive development, and further cross-cultural as well as training studies are needed to confirm the results presented here.

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