Multimodal interactions among infants in three radically different learning environments

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Abstract

This article presents an exploration in natural, multimodal interactions surrounding infants. In particular, the exploration concerns observations of spontaneous interactions at infants' homes in three culturally different learning environments: a Western urban community, a non-Western rural community, and a non-Western urban community. The observations were analyzed in terms of (speech-accompanied) gestures addressed to and produced by the infants. Results indicate that the type and frequencies of non-verbal utterances differed drastically over the three learning environments, including the ways these were accompanied by verbal utterances. The conclusion is that in order to obtain a good insight into the multimodal capacity of human language and its development, it is essential to carry out more research into non-WEIRD communities.

Introduction

Language is invariantly multimodal, so acquiring language not only involves acquiring the words and grammar of the language, but it also involves acquiring non-verbal behaviors such as eye-gaze, gestures and body language (Bates, Thal, Whitesell, Fenson & Oakes, 1989; Bruner, 1975; Goldin-Meadow, 2014; Vigliocco, Perniss & Vinson, 2014). The relation between non-verbal communication and language acquisition has been widely studied in Western middle class families (Capirci, Contaldo, Caselli & Volterra, 2005; Özçalışkan, & Goldin-Meadow, 2005; Rowe & Goldin-Meadow, 2009b), but much less so among infants of non-Western origin. This is surprising, since the WEIRD (Western, Educated, Industrialized, Rich and Democratic; Henrich, Heine & Norenzayan, 2010) countries only make up for about 12% percentage of the world's population. So, in order to fully understand the human capacity for language acquisition, more research is required on how multimodal interactions develop and are used among infants from non-WEIRD communities.

Such research ties in with Schieffelin and Ochs' (1986) notion of *language socialization* that “concerns two major areas of socialization: *socialization through the use of language* and *socialization to use language*” (p. 163). However, research on language socialization from non-WEIRD communities has largely focused on the verbal domain (Vigliocco et al., 2014). In Western, middle-class cultures children are frequently spoken to in short clear utterances with intonation patterns that typically highlight the focus of the utterances (Clark, 2009; Fernald, 1985). However, in many non-Western cultures children are infrequently spoken to (Casillas, Brown & Levinson, 2019; Cristia, Dupoux, Gurven & Stieglitz, 2019); they often left on their own and only spoken to after they have started talking themselves (Lieven, 1994). Until then, children are either

addressed to by older children, such as siblings (Harkness, 1977; Rabain-Jamin, 2001) or depend on overheard speech for learning language (Schneidman & Goldin-Meadow, 2012). Yet, language socialization does not only occur in the oral modality; it also involves other modalities, such as hand gestures, facial expressions and action-oriented forms of socialization (Goldin-Meadow, 2014; Gaskins, 2006; Schieffelin & Ochs, 1986). Some studies have investigated non-WEIRD language socialization in non-verbal modalities (e.g., Callaghan et al., 2011, LeVine et al., 1996), but still little is known about the different multimodal practices that can be observed in these communities.

In this article, we explore both verbal and non-verbal behaviors used in the language socialization of infants from three radically different cultural communities: a Western urban community from the Netherlands, a non-Western rural community from Mozambique, and a non-Western urban community from Mozambique. In particular, we explore the use of a wide range of multimodal communicative behaviors addressed to infants, as well as those produced by infants. We specifically focus on the use of *gestures*, i.e. utterances of visible bodily actions (Kendon, 2004). Our exploration concerns novel analyses of natural observations recorded longitudinally on two different occasions in the infants' home environment at the infants' ages of 1;1 and 1;6 years. The same observations were analyzed previously concerning infants' engagement (Mastin & Vogt, 2016) and the communicative intentions of infant-directed speech (Vogt, Mastin & Schots, 2015). In the present study, we present the occurrence frequencies of 10 different gestures as they are addressed to and produced by the infants in the three communities. We analyze how these frequencies compare over cultural communities, how they change over time, to what extent they are accompanied by a verbal utterance, and how gestures are combined with speech.

Multimodality in language socialization

Gesture and language acquisition

Kendon (2004) defines gestures as expressions (or utterances) of visible bodily actions. Infants tend to use only three types of gestures: ritualizations, deictic gestures and symbolic gestures (Tomasello, 2003). Ritualizations are bodily actions that infants produce to get something done effectively. Starting off as ‘real actions’, these actions tend to become ritualized as a means for the infant to communicate the effect that they intend to achieve. For example, when they are picked up by their caregivers, infants’ both arms are raised. Through repetition, they learn that simply raising their arms effectively communicates ‘pick me up’, and this action thus becomes ritualized. Deictic gestures are actions typically used to draw someone’s attention to something externally, such as a nice toy or some interesting event. Typical examples include pointing and showing. Symbolic (or referential) gestures are actions that stand for something externally, often in an iconic manner (Goodwyn & Acredolo, 1993). Examples include spreading the arms to indicate the size of something or making a drinking motion with the arm and hand to indicate one is thirsty. In the present study, we focus on a variety of these types of gestures. The standard definition of gestures assumes that they occur without the target objects or events being present. We extend this interpretation by also including certain forms of visible actions on objects or events, provided they have an expressive intention, because they have similar communicative functions and could therefore have similar effects on infants’ language development (cf. Zukow-Goldring, 1996). These extended gestures include demonstrations of object affordances (e.g., demonstrating how a toy car drives) or communicative actions that may become ritualized (e.g., patty cake games).

Language and gesture go hand in hand. When we speak, we automatically produce gestures (Kendon, 2004; McNeil, 2000) and many scholars have recognized that the two are so closely

related that the cognitive mechanisms responsible for their processing must be interrelated (Goldin-Meadow, 2014; Kita & Özyürek, 2003). This suggests that they are acquired together and that the acquisition of one may support the acquisition of the other and vice versa (Bates et al., 1989; Iverson & Goldin-Meadow, 2005).

There is ample evidence showing that gesture and language development are, indeed, related. While infants start to point imperatively to things they want by the age of 9-12 months (Bates, Camaioni & Volterra, 1975), they start to point to things in a declarative manner, just to share their attention with an interlocutor by the age of 12 months and after they start to produce their first words (Liszkowski & Tomasello, 2011). Moreover, the age of onset of such pointing gestures strongly relates to later vocabulary size (Carpenter, Nagell, Tomasello, Butterworth & Moore, 1998). Similar findings also hold for other more symbolic gestures. For instance, the use of *iconic* gestures (i.e. hand movements that bear a close resemblance to the activity or object it relates to) correlates strongly to infants' language comprehension and production (Bates et al., 1989), and size of the repertoire of gestures that an infant produces predicts later vocabulary size (Rowe & Goldin-Meadow, 2009b). Moreover, infants unable to express two words within one utterance can make use of a gesture+speech combination to express a two-word idea (Goldin-Meadow & Butcher, 2003). Furthermore, producing gesture+speech combinations predicts the onset of the two-word stage for Italian and American children, even though Italian children acquired and used a wider range of gestures than American children (Iverson, Capirci, Volterra & Goldin-Meadow, 2008).

Not only gestures produced by infants are important, also the gestures addressed to them are important. First, because the amount and variability of gestures addressed to infants, predict the number of gestures they produced themselves (Iverson et al., 2008; Rowe, Özçalışkan &

Goldin-Meadow, 2008), which thus relates to their language development. Moreover, the non-verbal aspects communicative acts can provide the child with all sorts of cues (pointing gestures, eye-gaze, intonation, etc.) that help them pay attention to what is central for the situation, which in turn allow them to learn the linguistic parts (e.g., word-meaning mappings) of an utterance (Hollich et al., 2000).

Accepting speech and gesture as an integrated multimodal system for communication, it is perhaps more important to understand how the integrated package is acquired than to understand how the individual modalities are acquired. By taking such an approach, it is also imperative to look at the social ecology of the developing child (Hoff, 2006; Vygotsky, 1978; Zukow-Goldring, 1996), which not only focuses on the (symbolic) signals produced in interaction, but also considers how full-body affordances, immediate pragmatic context, cultural practices, individual competences and so forth are incorporated in the communicative development of the child. Looking at caregiver-child interactions, these not only occur through speech, deictic gestures or symbolic gestures. Following Zukow-Goldring (1996; 1997), one of the most basic ways to direct an infant's attention to an object or action is by orienting the infant's body in the direction of an object or by controlling the infant's body to perform a particular action (e.g., by raising an infant's arm to focus her attention to the action of putting her arm through the sleeve of her shirt while dressing). Such gestural activities allow the infant to focus attention to those aspects of her environment that are considered important by the caregiver during interaction, which may be determined at one moment by the caregiver's parenting goals and at another time by tasks or events that are naturally part of the present situation.

In the same sense, the role of multimodal communication within the realm of interactive play is considered a crucial social ecology (Vygotsky, 1978; Zukow-Goldring, 1996). It is often

within these situations that children are motivated to explore their curiosity and thus trigger learning, especially when the playing occurs within the child's zone of proximal development (Vygotsky, 1978). It is here where there occur many forms of ritualized activities, especially in turn-taking events, that involve some repetition, which in turn facilitates learning.

Gesture and language acquisition in a cross-cultural perspective

Seeing language acquisition as a multimodal activity also requires one to consider the multimodal aspects of language socialization across cultures and other social contexts (Chavajay & Rogoff, 1996; Hoff, 2006; Schieffelin & Ochs, 1986). While there are various studies that have compared the use of gesture in relation to language acquisition across social contexts and cultures (e.g., Iverson et al., 2008; Tamis-LeMonda, Song, Leavell, Kahana-Kalman & Yoshikawa, 2012; Rowe & Goldin-Meadow, 2009a), not many have looked at non-WEIRD cultures.

Few studies have demonstrated that infants across a variety of cultures, including non-WEIRD ones, start using pointing gestures around the age of 12 months (Liszkowski, Brown, Callaghan, Takada, & De Vos, 2012; Callaghan et al., 2011; Salomo & Liszkowski, 2012). However, the rate with which pointing gestures or other types of deictic gestures are used –both addressed to and produced by infants– varies considerably across cultures (Callaghan et al., 2011; Lieven & Stoll, 2013; Salomo & Liszkowski, 2012). While studies show that the onset of various non-verbal behaviors is comparable across different cultures, WEIRD communities tend use more gestures in a declarative manner, especially pointing, during language socialization (both for and by infants) than non-WEIRD communities (Callaghan et al., 2011; Lieven & Stoll, 2013; Salomo & Liszkowski, 2012).

Very few studies have investigated the development and use of gestures for and by children in sub-Saharan Africa. One exception is the study by Kunene Nicolas, Guidetti and Coletta (2017),

which compared the development of speech and gesture in narratives between Zulu and French speakers of 5-years old, 10-years old and adults. Interestingly, they found that Zulu children produced longer narratives using more co-speech gestures than French children. Moreover, Zulu speakers used more representational (i.e. iconic) gestures than French speakers. These findings are in line with the fact that Zulu have a long oral narrative tradition, like many non-WEIRD cultures and unlike many WEIRD cultures. Kunene Nicolas and colleagues explained their findings by a difference in the type of speech acts produced between the two cultures, leading to the production of different types of gestures.

It is not only culture that provides different social contexts, also socio-economic status (SES) tends to generate qualitatively and quantitatively different language socialization practices (Hoff, 2006). Various studies have found that children growing up in families of high SES receive quantitatively much more verbal and non-verbal input, and with more variation than children from low SES families (Hart & Risley, 1995; Rowe, Özçalışkan & Goldin-Meadow, 2008). Children of high SES also tend to talk more varied using more words in longer sentences (Hart & Risley, 1995) and produce more gestures (Rowe & Goldin-Meadow, 2009a) than children of low SES.

Parenting goals and language socialization

Years of ethnographic research have found profound differences in language socialization practices across the world's cultures (Schieffelin & Ochs, 1986; Gaskins, 2006; Lieven, 1994; Chavajay & Rogoff, 1993). These studies have yielded various classifications of ways by which children are socialized, such as *child-centered* socialization and *situation-centered* socialization (Schieffelin & Ochs, 1986). Child-centered socialization practices relate to what is often observed in middle-class Western families who focus on talking directly to children, providing them with all sorts of extra-linguistic cues aimed to teach children how to speak. Situation-centered

socialization practices concern language environments of children often observed in non-Western communities where children are being socialized in relation to what is demanded for the situation at hand, which often does not involve child-directed speech or explicit instruction aimed towards language learning, so these children may have to rely more on overheard speech (Shneidman & Goldin-Meadow, 2012).

Many practices that relate to a certain style of socialization (whether it concerns language or some other developmental target) can be related to communities that have similar parenting goals and lifestyles (Greenfield, 2009; Keller, 2007; 2012). To characterize how different communities adhere to particular practices, Heidi Keller (2007; 2012) has distinguished three learning environments: a prototypical Western urban environment, a prototypical non-Western rural environment and a hybrid non-Western urban environment. The prototypical Western urban environment coincides substantially with the commonly studied Western middle-class families. These are typically small nuclear families, whose lifestyle is highly individualistic and based on a knowledge-driven market economy. Parenting goals relate to this lifestyle and concern the fostering of *individual psychological autonomy*: early cognitive development is considered very important, as this helps the offspring to be successful in formal education, which in turn provides good career prospects in the Western urban society. Although relatedness is fostered, the focus is on being able to fare well individually. Socialization is characterized as child-centered, typically containing many face-to-face interactions aimed to support cognitive development.

The prototypical non-Western rural learning environment typically concerns extended families containing multiple nuclear families of multiple generations, who have a subsistence-farming lifestyle. Subsistence farming requires that all individuals participate responsibly in the various activities that need to be carried out, organized in a hierarchical manner. Parents aim at

fostering *action autonomy*: “an individual’s capacity to act in a responsible and self-controlled way with respect to fulfilling responsibilities and obligations” (Keller, 2012, p. 14). Formal education is not considered very important; instead children are expected to help with household chores or straightforward farming activities from a young age onward. These activities may include taking care of the youngest. Caregiving in these communities is not necessarily the main task of the primary caregiver, but infant caregiving is often the responsibility of older siblings, aunts or grandparents. Body contact is considered important to foster social relatedness and motor skills. Language socialization is more situation-centered, where the infants are immersed in the conversation between adults and often only addressed to when the situation asks for it –for instance, when children are asked to do a minor chore or to guide their behavior towards others.

Keller (2012) classifies the non-Western urban communities as a hybrid between the two prototypical learning environments. Since many people living in the non-Western cities have migrated there relatively recently from the rural communities, they have to deal with the market-based lifestyle of these cities while still very much being attached to their rural traditions. They often live in extended families, although kinship relations may be a bit further apart, so communal responsibilities and social relatedness is considered very important. However, due to the demands inherent to the market-based economy, formal education has become more important, and so also the fostering of cognitive skills that help them be more successful in education is recognized as important. Caregivers thus aim to foster what Keller (2012) calls *communal psychological autonomy*. Language socialization, too, may be considered as a hybrid between child-centeredness and situation-centeredness. Increased amounts of language interactions directed to children, but the manner in which interactions are organized seem more in line with a situation-centered style.

Language socialization has been relatively understudied in sub-Saharan Africa, and those that investigated language socialization practices have mostly focused on verbal communication (Alcock & Alibhai, 2013; Demuth, 1986; Rabin-Jamain, 2001) or on the relation between communication and more general parenting practices (Harkness, 1977; LeVine et al., 1994). Generally, all studies found that –compared to Western language socialization styles– African practices tend to fit a situation-centered socialization with fewer child-directed speech containing relatively many imperatives.

The present study

Our research focuses on the multimodal language socialization practices of infants from three different communities that represent the three learning environments characterized by Keller (2012). A group of Dutch middle class families represents the prototypical Western urban learning environment, a rural community from Mozambique represents the prototypical non-Western rural environment and a group of families from urban Mozambique forms the hybrid non-Western urban environment. We observed the natural interactions of a total of 40 infants three times over the course of their second year of life, when they were 1;1, 1;6 and 2;1 years old. However, we only include analyses from the observations at 1;1 and 1;6, as the analyses at 2;1 are incomplete.

Previous analyses of these observations generally confirmed that the socialization practices of the three communities very much match to those that one might expect based on Keller's (2012) characterization. For instance, Dutch infants spent more time engaged in joint attention than their Mozambican counterparts, who spent more time engaged in observing others' activities or in dyadic person interactions that involve no third object or event (Vogt & Mastin, 2014). Moreover, the amount of time Mozambican infants spent in observing others and being engaged in dyadic person interactions revealed a positive correlation to later vocabulary size, whereas the time rural

infants from Mozambique spent in joint attention had a negative correlation to vocabulary size (Mastin & Vogt, 2016). In terms of child-directed speech, we observed that at 1;1 years, Dutch infants were exposed to ten times more utterances than rural Mozambican infants and to twice more utterances than urban Mozambican infants (Vogt et al., 2015). Looking at the communicative intentions of the speech addressed to these infants, we found that –relatively speaking– Dutch caregivers more often produced utterances that had a cognitive intention (e.g. object naming, counting, etc.), rural Mozambican caregivers more often used imperatives, and urban Mozambican caregivers produced more speech with a socio-emotional intention (Vogt et al., 2015). These findings all demonstrate how Dutch caregivers seem to focus more on fostering cognitive (language) development, rural Mozambican caregivers more on (communal) action autonomy and urban Mozambican caregivers more on communal psychological autonomy.

In the present study, we analyze how the verbal and non-verbal modalities are used in these three communities. In particular, we investigate the gestures that are produced for and by the infants by assessing their occurrence frequencies, and how often they are accompanied by a verbal utterance. Moreover, we analyze to what extent speech-accompanied gestures are semantically coherent, and how often speech and gesture form complementary gesture+speech combinations (cf. Goldin-Meadow & Butcher, 2003). Some partial and preliminary findings of these analyses have been published previously in the proceedings of *CogSci* (Vogt & Mastin, 2013; de Jong and Vogt, 2016) and the TIGER workshop (Vogt, Masson-Carro & Mastin, 2013).

Methods

Participants

Families with infants of 1;1 years old at the start of our longitudinal study were recruited ($N=40$); 12 from the Netherlands, 14 from rural Mozambique and 14 from urban Mozambique. In the

Netherlands, all participants are native speakers of Dutch and are from families with high maternal and paternal education; all mothers completed a school of higher education. In rural Mozambique participants are monolingual speakers of Changana (a Southern-Bantu language, spoken in Southern Mozambique and parts of South Africa), and maternal education is very low: mothers received either no or very little formal education. Urban Mozambican families are mostly bilingual speakers of Portuguese and Changana (or Ronga - a mutually intelligible dialect of Changana), and the maternal education was significantly higher than in the rural community, but drastically lower than in the Dutch sample. Table 1 summarizes the main demographics of our sample. Data were collected in the period from 2010 to 2013.

During recruitment, the general goals and procedures of the study were explained in the participants' native languages (in Mozambique, local research assistants were trained to communicate with them). We informed participants that their participation was voluntary, that they would not receive any direct benefits, and that they could retract from our study at any time for any reason. All families provided voluntary informed consent. The study was carried out according to the guidelines of the Research Ethics Committee of Tilburg University.

Procedure

We visited the families at their homes when the infants were around 1;1 and 1;6. During these visits, we videotaped infants' social interactions in their home environment. We instructed caregivers to continue what they were doing prior to our visit and behave as they normally would without our presence. These instructions were given to elicit naturalistic behavior. In Mozambique, an accommodation session approximately one week prior to the data collection was carried out to familiarize participants with the presence of a foreign person observing them with a video camera. We assumed that such an accommodation session was unnecessary in the Netherlands, as infants

would have been exposed to Caucasian persons with video equipment before.

Table 1. Demographics of the participants' sample.

Demographics	Netherlands (N=12)	rural Mozambique (N=14)	urban Mozambique (N=14)
Female/male	6/6	7/7	5/9
Avg age first visit (<i>SD</i> in days)	1;1.8 (18)	1;1.8 (26)	1;1.6 (28)
Avg age second visit (<i>SD</i> in days)	1;5.10 (19)	1;5.28 (25)	1;5.12 (30)
Avg family size	3.3 (0.8)	8.2 (5.8)	7.4 (4.4)
Avg birth order	1.5 (0.8)	3.2 (2.4)	2.5 (1.5)
<i>Maternal education^a</i>			
No education	0	6	1 ^a
Primary education	0	8	11
Secondary education	0	0	1
Higher education	12	0	0

Note: ^a Maternal education data from one urban Mozambican participant is missing.

On each visit, we videotaped the infants for 45 to 75 minutes until we obtained approximately 30 minutes of audible material in which the infant would be clearly visible. Where

possible, the camera was placed on a tripod approximately 5 to 15 meters away from the infant. This was usually possible in rural Mozambique, but in the Netherlands and in some urban Mozambican households, space was too confined, and filming had to be done by hand, 1 to 5 meters away.

During our visits, several survey questions were asked to collect demographic data and other related background information from our participants. In addition, we administered adapted versions of the MacArthur-Bates CDI to obtain estimates on vocabulary development, which are not presented in the present article (see Vogt et al., 2015, for results from these data).

Analysis

For each visit, we identified extensive segments of video fragments totaling 30 minutes for analysis. The segmentation procedure was necessary to exclude episodes during which the infant was off-camera, asleep, disturbed or interacting with the researchers. In addition, extended periods of breastfeeding (more than 3 minutes) were excluded to reduce a bias towards interactions typically occurring during breastfeeding. From these segments, we transcribed the infant-directed speech and the infants' own speech, and we coded the infant-directed gestures and the infants' own gestures. Below we describe our transcription and coding methods.

Speech. All infant-directed speech and infant-produced speech during the 30-minute segments was transcribed by research assistants in ELAN (Wittenburg, Brugman, Russel, Klassmann, & Sloetjes, 2006). For Dutch, the research assistants were trained undergraduate students and native speakers of Dutch. In Mozambique, the research assistants were bilingual and literate in Portuguese and Changana, and they were directly supervised by one of the researchers while transcribing the videos. Changana speech was transcribed phonetically following the standard Changana/Ronga orthography (Bachetti, 2006). Vocalizations, such as laughter, cries, attention

getters and non-linguistic exclamations, were marked separately. In addition, all unintelligible speech was identified as unknown speech. The Mozambican transcriptions were translated first into Portuguese and subsequently into English.

Gesture coding. A range of non-verbal behaviors produced during episodes of *joint engagement* (Bakeman & Adamson, 1984; Mastin & Vogt, 2016) was coded according to the following 10 categories. In the descriptions, we refer to the actor and addressee, who can either be infant or caregiver. Moreover, we annotated these behaviors irrespective of whether or not they were accompanied by a verbal utterance.

1. *Pointing*. The actor points at an object either using his index finger, hand or some other body part, in order to draw the addressee's attention to the target object.
2. *Showing*. The actor holds up an object in order to draw the addressee's attention to it.
3. *Demonstrating*. The actor manipulates an object to show the addressee the affordance(s) of that object, or the type of actions that can be performed upon it.
4. *Reaching*. The actor moves his hand towards a target object with the intention to obtain it, but does not obtain this object. Also *requests for objects* by extending the hand with the palm faced upward were included in this category.
5. *Offering*. The actor offers or gives an object to the addressee.
6. *Taking*. The actor takes an object from the addressee's possession.
7. *Conventional gestures*. This category comprises gestures that are symbolic of nature, such as emblematic or representational gestures, but also gestures that bear an iconic relationship with their referent (cf. Tomasello, 2003). For example, waving bye-bye, or indicating the size of an object with the hands.

8. *Ritualized play*. This category accounts for all ritualized interactions or displays that occur between actors and addressees. For instance, dancing, clapping hands or turn-taking games, such as patty-cake. Typically, these behaviors occur in a repeated turn-taking manner.
9. *Embody*. The actor performs a physical action onto the addressee's body, such as redirecting or correcting the addressee's position, or taking his or her hand to lead the way (cf. Zukow-Goldring, 1996).
10. *Attention getter*. This category comprises any gesture that seeks for the attention of the addressee, such as tapping one's shoulder.

Various trained researchers, including the authors, coded the gestures. We assessed inter-rater reliability by having approximately 10% of the videos coded by a second annotator. Analysis yielded an inter-rater agreement of 74.91% (Cohen's kappa=0.64) for all infant-directed gestures and an agreement of 69.75% (Cohen's kappa=0.62) for all infant-produced gestures. Given the naturalistic nature of the data, these scores indicate a substantial agreement (Landis & Koch, 1977).

Five analyses. Using the annotations, we present the following five analyses:

1. Occurrence frequencies of infant-directed gestures.
2. Occurrence frequencies of infant-directed speech-accompanied gestures.
3. Occurrence frequencies of different types of infant-directed speech-accompanied gestures.
4. Occurrence frequencies of infant-produced gestures.
5. Occurrence frequencies of gesture+speech combinations directed to and produced by infants.

In the first two analyses, we only look at the total numbers in an aggregated fashion. For analyses 3 and 4, we extend this to look at each of the 10 different gesture types. For all analyses we compare the three learning environments, except for the infant-produced gesture+speech combinations where we only compare the Dutch and urban Mozambican communities.

Results

Analysis 1: Infant-directed gestures

In the first analysis, we look at how the absolute total number of gestures produced for the infants vary across the three communities and the two age groups, irrespective of whether the gestures were accompanied by speech. Figure 1 shows that at 1;1 urban Mozambican caregivers on average produced the most gestures for the children, followed by Dutch caregivers and rural Mozambican caregivers, respectively. Means and standard deviations are provided in Table A1 in the Appendix. When children were 1;6 years old, Dutch caregivers produced more gestures than urban Mozambican caregivers, again followed by rural Mozambican caregivers. A 3 (location) x 2 (age) mixed design ANOVA revealed no main effect for location, $F(2,37)=2.42$; $p=.103$, nor for age, $F(2,37)=0.31$; $p=.580$. However, there was a small interaction effect, $F(2,37)=4.85$; $p=.013$; $\eta^2=.065$. Post-hoc pairwise comparisons with Bonferroni corrections show that at 1;1 the total number of infant-directed gestures in urban Mozambique is significantly higher than in the Netherlands ($p=.041$) and rural Mozambique ($p=.008$), but no significant differences were found when infants were 1;6. The interaction is caused by a significant increase in infant-directed gestures in the Netherlands from 1;1 to 1;6 ($p=.015$), while in Mozambique no significant age differences were observed.

Figure 1. Boxplot showing the occurrence frequencies of infant-directed gestures for all locations and age groups.

Analysis 2: Infant-directed speech accompanied gestures

In our second series of analyses, we counted the number of infant-directed gestures accompanied by some verbal utterance produced by the actor of the gesture, whether or not the verbal utterance had any semantic relation to the gesture. Figure 2 (left panel) shows a drastically different picture compared to the previous analysis (Figure 1), which also included gestures not accompanied by speech. Here we see that the average numbers of speech-accompanied gestures produced in the Netherlands were more or less similar to the numbers observed in urban Mozambique and both numbers drastically exceeded the numbers of speech-accompanied gestures produced in rural Mozambique. A 3 x 2 mixed design ANOVA reveals a main effect of location on occurrence, $F(2,37)=7.96$; $p=.001$; $\eta^2=0.26$, but no main effect of age, $F(2,37)=3.67$; $p=.063$. However, there was a significant interaction effect, $F(2,37)=8.09$; $p=.001$; $\eta^2=0.07$. Pairwise comparisons show that the occurrence frequencies in the Netherlands and urban Mozambique were significantly

higher than in rural Mozambique ($p<.001$). The interaction effect can be explained by developmental increases in speech-accompanied gestures in the Netherlands ($p=.002$) and rural Mozambique ($p=.022$), but not in urban Mozambique.

The difference between the occurrences observed for all gestures irrespective of them being accompanied by speech and when they are accompanied by speech can be explained by the differences in the amount of speech addressed to the infants between the three communities. Previous analysis of the amount of infant-directed speech (IDS) has revealed that Dutch caregivers talk to their infants 5 to 10 times more often than rural Mozambican caregivers and about 2 times more often than urban Mozambican caregivers (Vogt et al., 2015). However, these differences in IDS do not entirely explain what is happening, because there is no one-to-one relation between the amount of IDS and reduction of gestures when accompanied by speech. It is therefore imperative to also look at the proportion of gestures accompanied by speech in the different communities.

Figure 1. Boxplot showing the occurrence frequencies (left) and the proportions (right) of infant-directed gestures when accompanied by a verbal utterance for all locations and age groups.

Figure 2 (right panel) shows clear differences in the average proportions of speech-accompanied gestures compared to all gestures (see Table A2, bottom row, for all means and standard deviations). To calculate these proportions, we divided the total number of speech-accompanied gestures (cf. Fig. 1) by the total number of gestures (cf. Fig. 2, left) per location per age group. The ANOVA confirms there is a main effect of location, $F(2,37)=18.40$; $p<.001$; $\eta^2=0.43$, and it also finds a small main effect of age, $F(1,37)=7.44$; $p=.010$; $\eta^2=0.04$. Pairwise comparisons show that at 1;1 the proportion of speech-accompanied gestures in the Netherlands is significantly higher than in urban Mozambique ($p<.001$), which in turn is higher than the proportion observed in rural Mozambique. At 1;6, the proportion of speech-accompanied gestures observed in the Netherlands is also significantly higher in urban Mozambique ($p=.011$) and rural Mozambique ($p<.001$), but the difference between both Mozambican communities is not significant ($p=.200$). The effect of age is due to a significant increase in the proportion observed in rural Mozambique ($p=.001$). No interaction effect was observed, $F(2,37)=2.61$; $p=.087$. These findings suggest that in the Netherlands gestures were more often used alongside some verbal utterance, but much less so in Mozambique, where almost half of the infant-directed gestures were produced silently.

Analysis 3: Different infant-directed speech-accompanied gestures

Figure 3 shows the frequency distributions of each type of infant-directed gesture when accompanied by speech. Table A2 provides all means and standard deviations. Each panel shows a boxplot of the occurrence frequencies of one particular type of gesture at the different locations and age groups. Clear differences can be observed between the Netherlands and Mozambique, with deictic gestures pointing, showing and demonstrating, as well as conventional gestures occurring substantially more often in the Netherlands compared to Mozambique. All other differences are more complex.

Figure 3. The occurrence frequency of all infant-directed speech-accompanied gestures per location and age group.

For each different gesture, we carried out a 3 (location) x 2 (age) mixed design ANOVA. A complete overview of the results is found in Table B1 in Appendix B. For all gestures, except reaching, taking and ritual play, the ANOVAs revealed main effects of location on the frequency of gesture use ($p < .05$). Post-hoc pairwise comparisons with Bonferroni corrections confirmed that pointing, showing, demonstrating and conventional gestures occurred more frequently in the Netherlands than in rural Mozambique ($p \leq .002$) and urban Mozambique (for pointing $p = .034$; for all other gestures $p < .002$). Offering occurred more frequently in urban Mozambique than in rural Mozambique ($p = .037$). Embody gestures occurred more frequently in urban Mozambique than in rural Mozambique ($p < .001$) and tended to occur more often than in the Netherlands

($p=.053$). Finally, attention getters occurred more frequently in urban Mozambique compared to the Netherlands and rural Mozambique ($p<.001$).

Main effects of age were only found for pointing ($p<.001$), taking ($p<.05$) and conventional ($p<.05$) gestures. Interaction effects were observed for pointing, showing, demonstrating ($ps<.001$) and conventional ($p<.05$) gestures. Pairwise comparisons revealed that the effects for pointing ($p=.002$) and conventional ($p=.05$) gestures were entirely caused by significant increase over time in the Netherlands. The effect for taking was due to increases in the Netherlands and rural Mozambique ($ps<.01$). The interactions for showing and demonstrating were caused by significant decreases in urban Mozambique.

Summarizing, most clear differences between the learning environments concern those gestures often used in declarative (pointing, showing and demonstrating) or symbolic (conventional) ways, which all occur significantly more often in the Netherlands compared to Mozambique. Dutch and urban Mozambican caregivers used embody gestures more often than rural Mozambicans, and urban Mozambican caregivers used attention getters most often.

Analysis 4: Infant gestures

Figure 4 shows the average occurrence frequency of all gestures produced by infants, irrespective of whether they were accompanied by a verbal utterance. What is striking is that in this analysis there are less pronounced differences in the numbers of gestures produced by the infants at the different locations, nor at the different ages. The 3x2 mixed design ANOVA, indeed, revealed no main effects for location, $F(2,37)=0.37$; $p=.695$, and age, $F(1,37)=3.16$; $p=.084$, but it did reveal a small interaction effect, $F(2,37)=4.09$; $p=.025$; $\eta^2=0.07$. The post-hoc analyses revealed that this interaction was due to an increase in gesture production by Dutch infants ($p=.017$), but not by Mozambican infants.

Figure 4. Occurrence frequencies of the total number of gestures produced by infants irrespective of them being accompanied by speech. The graph shows the frequencies for all locations and age groups.

Looking at the different gesture types (Figure 5; see Table A3 for details) we see that, although we did not observe much difference in overall gesture use between the three learning environments, there were substantial differences in the types of gestures the infants use across the environments. Most striking differences concern the pointing gesture, which revealed main effects of location, $F(2,37)=24.38$; $p<.001$; $\eta^2=0.43$, and age, $F(1,37)=12.44$; $p=.001$; $\eta^2=0.12$. Clearly, Dutch infants point significantly more often at both ages, but the amount by which they do so drastically increases with age. Since this increase was only observed in the Netherlands, and not in Mozambique, we also observed an interaction effect, $F(2,37)=9.71$; $p<.001$; $\eta^2=0.18$.

Conventional gestures also have a main effect on location, $F(2,37)=20.92$; $p<.001$; $\eta^2=0.33$, and occur most frequently among Dutch infants, as do embody gestures ($p=.009$; $\eta^2=0.12$). Demonstrating has a main effect on location, $F(2,37)=13.92$, $p<.001$; $\eta^2=0.26$, and

occurs more often in rural Mozambique compared to the Netherlands and urban Mozambique ($ps<.001$). Reaching also has a main effect on location, $F(2,37)=4.57$; $p=.017$; $\eta^2=0.13$, and occurs more often in rural Mozambique compared to the Netherlands ($p=.005$). Finally, attention getters, too, show a main effect on location, $F(2,37)=8.01$; $p=.001$; $\eta^2=0.20$, and occur more often in rural and urban Mozambique than in the Netherlands ($ps<.003$).

In addition to the one found for pointing, we observed an age effect on the occurrence of offering, $F(1,37)=18.76$; $p<.001$; $\eta^2=0.18$, which increased in all communities ($ps<.05$) indicating that children with age become more inclined to share objects or food with others. Small interaction effects were found for reaching, embody and attention getters ($ps<.05$), suggesting that the already mentioned location effects for these gestures may change over time.

Figure 5. The occurrence frequencies of all infant gestures per location and age group.

Analysis 5: Gesture+speech combinations

For the next series of analyses, we were interested to explore to what extent the information conveyed in the gesture was semantically coherent with the information conveyed in the speech of both caregiver and infant. Moreover, in the case it was semantically coherent, we were curious to see to what extent the referents of both modalities were aligned (e.g., point-to-dog plus say ‘dog’) or complementary (e.g., point-to-dog plus say ‘fetch’) to each other.

To achieve this, we coded for all speech-accompanied gestures whether the semantic intention of the gesture was coherent with (a part of) the verbal utterance addressed to or produced by the infant (Cohen’s $\kappa=0.66$). Gesture and speech are coherent when the semantic intentions were related (e.g., point-to-dog plus say ‘fetch’, when intending to say something like “fetch the dog”). They are not coherent when the semantic intentions do not relate (e.g., point-to-dog plus say ‘drink’, when intending to ask the infant if she want to drink). In addition, we coded for all coherent gestures whether its semantic content (or referent) matched (or aligned) the reference of one (or more) words from the utterance or whether the content was complementary to the utterance, thus signaling a supplementary idea (Cohen’s $\kappa=0.90$). Instead of coding the gestures of all participants at all ages, we only coded the infant-directed co-speech gestures at 1;1 and the infant-produced gestures at 1;6. Moreover, since rural Mozambican infants at 1;6 hardly produced any intelligible speech, only the infant-produced gestures from the Netherlands and urban Mozambique were coded.

Infant-directed gesture+speech combinations. Figure 6 shows the results for the infant-directed gestures at 1;1. The left panel shows the percentage of speech-accompanied gestures that were semantically coherent with the speech. A one-way ANOVA with planned contrasts (Netherlands vs Mozambique and rural vs urban Mozambique) revealed a significant effect of location on the

percentage of coherent gestures, $F(2,35)=8.64$; $p<.001$. In particular, Dutch caregivers produced relatively more coherent gestures, $M=86.35$; $SD=3.87$, than Mozambican caregivers, $t(35)=3.47$; $p=.01$; $r=.51$. In turn, urban Mozambican caregivers produced a higher percentage of coherent gestures, $M=79.71$; $SD=6.63$, than rural Mozambican caregivers, $M=72.05$; $SD=12.13$; $t(35)=2.36$; $p=.02$; $r=.37$. These findings suggest that Dutch caregivers seem to use gestures in relation to their speech more coherently than Mozambican caregivers.

Figure 6. Semantic coherence (left) and proportion of complimentary gesture+speech combinations (right) for infant-directed gestures.

The right panel of Figure 6 shows the percentage of semantic coherent gestures of which the semantic content complements the content contained in the speech. A one-way ANOVA with planned contrasts as before revealed a significant effect of location on the production of complementary speech-gesture combinations, $F(2,35)=4.28$; $p=.02$. In particular, Dutch caregivers produced significant a lower percentage of complimentary speech-gesture combinations, $M=60.93$; $SD=13.97$, than Mozambican caregivers, $t(35)=2.56$; $p=.02$; $r=.40$. The difference between rural, $M=76.72$; $SD=13.94$, and urban $M=69.35$; $SD=11.95$, Mozambican caregivers was not significant, $t(35)=1.45$; $p=.16$.

Infant produced gesture+speech combinations. Figure 7 shows the results of the analysis for the gestures produced by the infants from the Netherlands and urban Mozambique at 1;6. For these analyses only 11 infants from each community were included (de Jong & Vogt, 2016). Since only 7 Dutch infants and 8 urban Mozambican infants produced one or more utterances accompanied with gestures, we refrain from a statistical analysis, but only report the descriptive statistics.

Figure 7. The left panel shows the percentage of gesture-speech combinations produced by infants that were semantically coherent. The right panel shows the percentage of semantically coherent gesture-speech combinations where the referent of the gesture complements that of the speech.

The left panel shows that semantic coherence appears around 80% in the Netherlands, while it is nearly 100% in Mozambique. Of all semantically coherent speech-accompanied gestures, 12% of the Dutch and 40% of the Mozambican combinations are complementary gesture+speech combinations.

As the boxplots show, the data are rather skewed. This is because some infants only produced one or two semantically coherent combinations during our observations. In order to get a somewhat more informative comparison, let us only consider those infants who produced more

than 5 semantically coherent combinations (9 Dutch and 8 Mozambican infants). Of these, only one Dutch infant produced complimentary gesture+speech combinations more than 25% of the time, while six Mozambican infants did so. Moreover, none of the Dutch infants produced these combinations more than 50% of the time, while 3 Mozambican infants did. Although hard to generalize, these findings indicate that 1;6 years old Mozambican infants may combine speech and gesture more often to produce two-word ideas compared to their Dutch counterparts.

Discussion

In this article, we explore the multimodal language socialization practices of three different, more or less prototypical learning environments. In particular, we assessed the use of gestures in relation to speech addressed to and produced by infants of 1;1 and 1;6 years old from the Netherlands, rural Mozambique and urban Mozambique. The analyses reveal substantial differences in the frequencies and type of gestures used, the proportions by which the gestures are accompanied by speech, the semantic coherence between speech and gesture, and the rates with which gesture+speech combinations occur. The general conclusion is that the way gesture and speech are used in the three communities fit well with the parenting goals that the different (prototypical) learning environments have according to Keller (2007; 2012), where the Dutch social ecology fosters individual psychological autonomy, the rural Mozambican ecology fosters (communal) action autonomy, and the urban Mozambican hybrid environment fosters communal psychological autonomy.

Infant-directed gestures

To foster individual psychological autonomy, Dutch caregivers seem to use their gestures more to scaffold language learning compared to Mozambican caregivers and especially the rural ones. Dutch caregivers tend to use their gestures more often in combination with a verbal utterance, they

use more deictic and conventional gestures, their speech-accompanied gestures are more often semantically coherent with the speech, and the referents of their gestures more often support the meaning of words. These socialization behaviors could be more supportive for the development of the verbal language capacity than the behaviors observed in rural Mozambique.

In rural Mozambique on the other hand, caregivers often produce silent gestures, typically imperatives, such as reaching/requesting, offering and embody gestures. In contrast, they produce few deictic and conventional gestures. Moreover, speech-accompanying gestures were often not semantically coherent with the utterance, and when they were coherent, they more often provided complementary information. These caregivers, thus, seem to rely much on non-verbal communication using limited verbal utterances, with the aim of asking infants to carry out various tasks, often related to household chores, without bothering much about naming things.

In urban Mozambique, a more complicated picture revealed. The absolute number of gestures are –more or less– on a par with the Netherlands and substantially higher than in rural Mozambique, but the types of gestures used are more similarly distributed as in rural Mozambique. The rates of semantically coherent gestures in urban Mozambique, as well as gesture+speech combinations, were in between those observed in the Netherlands and rural Mozambique. It thus seems that urban Mozambican caregivers foster psychological autonomy by producing more interactional gestures that are more often accompanied by and better related to verbal utterances than in rural Mozambique, but remain more traditional in terms of the types of gestures they use with respect to their rural roots. This is in line with the characterization of a hybrid learning environment outlined by Keller (2007; 2012) and fits the evolution of learning environments from rural to urban communities proposed by Greenfield (2009).

The findings are in line with earlier analyses of the same data concerning child-directed speech (Vogt et al., 2015) and infant-engagement (Mastin & Vogt, 2016), which also revealed a close relationship with the prototypical learning environments. The distinction between the Netherlands and rural Mozambique further relates to differences between child-oriented and situation-oriented styles of language socialization (Schieffelin & Ochs, 1986). Moreover, while differences in cultural practices definitely play a crucial role, the findings also relate to findings from studies on differences in SES (e.g., Hart & Risley, 1995; Rowe et al., 2008; Rowe & Goldin-Meadow, 2009a). These studies have also revealed more scaffolding of cognitive skills, including higher frequencies of child-directed speech and gestures, in communities of high SES (viz. the Netherlands), compared to lower frequencies in communities of low SES (viz. Mozambique, and with urban Mozambicans having higher SES than rural Mozambique).

Infant-gestures

Unlike with infant-directed gestures, the average frequencies of all gestures produced by infants at the two ages are not significantly different. However, when looking at the types of gestures infants produce, the distribution of gestures reflects what was observed for infant-directed gestures—at least to some extent. Infants in the Netherlands produced more deictic gestures (i.e. gestures used to draw someone's attention to something) —especially pointing gestures— conventional gestures and embody gestures than those in Mozambique, except for the demonstrating gesture, which occurred most in rural Mozambique. Reaching (or object requests) also occurred most often in rural Mozambique. Attention-getters occurred more often in both rural and urban Mozambique compared to the Netherlands.

These findings suggest that infants develop in a way that reflects their social environment. In part this may be through mimicking the input infants receive, but it may also be a more

sophisticated response to their learning environment. For instance, in the Netherlands much socialization occurred through book reading activities or socially playing with toys, both in a richly supported language environment. These activities may induce some form of curiosity to learn about the objects, their affordances and relations between them, which in turn may evoke infants' frequently pointing to objects. In addition, the higher frequency of demonstrating gestures in rural Mozambique does not seem to reflect the input. Instead, this may be the result of infants' development of action autonomy in which their motoric skills tend to be fostered earlier than their cognitive skills (Keller, 2012). More advanced motor skills would allow them to explore more complex actions towards objects earlier, and perhaps practice them more often in social contexts, possibly in response to their caregivers.

Reaching (and requesting) for objects occurs substantially more often among Mozambican infants, and rural ones in particular. This reflects a more imperative style of language socialization, but could also be partly due to the setting of the Mozambican language environment, where adults seem to invest less time socializing their infants and where siblings, often not much older than 5 years, spend much time in caregiving. It seemed from the videos that sibling caregivers often set a stage of (friendly) competition where, especially the younger siblings were showing off towards the infants, triggering interest in getting hold on an object or a food-item, which in turn triggered many reaching gestures. Moreover, in addition to spending less time attending to infants, this competitive setting with sibling caregivers may also explain the increased amount of attention-getters observed in Mozambique. Hence, while siblings tend to provide scaffolds within Vygotsky's zone of proximal development, sibling caregiving could influence the development of gestural communication by establishing particular interactions that may be less subtle than those provided by adults (cf. Zukow, 1989).

Our findings are in line with findings from related cross-cultural studies, such as that of Callaghan et al. (2011) or Lieven and Stoll (2013). We also found that nearly all infants in all learning environments point by the age of 1;1, but the occurrence frequencies are considerably higher in the Netherlands than in Mozambique. We found that basically all infants used virtually all types of gestures by then, except for conventionals which were not observed with most Mozambican infants at both age groups. The differences in their occurrence frequencies appear to be related to the speech acts in which they are used (cf. Kunene Nicolas et al., 20xx). In relation to what we observed regarding the infant-directed speech acts, Dutch tend to use more declaratives, while Mozambicans more imperatives and socio-emotional utterances (Vogt et al., 2015), these appear to transfer to the non-verbal modality as well.

To conclude, our explorations demonstrate that the multimodal language socialization varies drastically among different learning environments. These differences can largely be explained by the different parenting goals, which reflect not only a specific culture, but also many other factors that define a specific learning environment. Since all typically developing humans acquire language, to understand the human capacity for learning language in a multimodal manner, it is therefore crucial to not only base theories on studies from WEIRD populations, but also on those of non-WEIRD populations. While our study has indicated some different pathways to language, much more research is required to gain a full understanding. This research should not only focus on the verbal modality, but also on the non-verbal modality as these are highly related in all populations.

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