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Development of Infant Pointing from 10 to 12 months: The Role of Relevant Caregiver Responsiveness

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Infants' pointing frequency is a predictor of their later language abilities. Yet, predictors of pointing frequency in the first year of life are not well understood. Study 1 explored what factors in infants and caregivers at 10 months would predict the pointing frequency of infants at 12 months ($N = 35$). Infant-driven predictors were infants' fine-motor skills and point-following abilities. Caregiver-mediated predictors were caregivers' pointing frequency and responsiveness toward infants' pointing. Relevant caregiver responsiveness at 10 months predicted infants' pointing frequency at 12 months, controlling for the other factors and infants' prior pointing frequency. Study 2 explored whether child-level factors influence caregivers' responsiveness ($N = 49$). We examined the hand shape of infants' pointing (whole-hand versus index-finger) and the presence of point-accompanying vocalizations. Infants' vocalization-accompanied points were more likely to elicit relevant responses from caregivers, while hand shapes played a less pronounced role. Together, the findings reveal an early emerging mutual relationship between infant pointing and caregiver behavior such that certain characteristics of infant pointing predict caregivers' responsiveness, and relevant responsiveness toward infants' pointing predicts the increase in infants' pointing frequencies.

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A common prelinguistic communicative tool for infants is the pointing gesture, which involves an extension of the hand or index finger toward an entity (Bates, Benigni, Bretherton, Camaioni, & Volterra, 1979). Infant pointing does not merely precede language as a communicative device but is a robust predictor of infants' later linguistic abilities (see Colonnesi, Stams, Koster, & Noom, 2010 for a meta-analysis). Infants' language skills are predicted both by the age of emergence (Butterworth & Morissette, 1996; Carpenter, Nagell, Tomasello, Butterworth, & Moore, 1998; Desrochers, Morissette, & Ricard, 1995), and the frequency of pointing (Esseily, Jacquet, & Fagard, 2011; Mundy et al., 2007; Özçalışkan, Adamson, & Dimitrova, 2016; Rowe, 2000), although most studies have focused on the latter as an indicator. Specifically, the frequency of the canonical index-finger pointing gesture, as opposed to the whole-hand pointing gesture which emerges a few months earlier (Liszkowski & Tomasello, 2011; Lock, Young, Service, & Chandler, 1990), is positively predictive of language acquisition (Lüke, Grimminger, Rohlfing, Liszkowski, & Ritterfeld, 2017).

Studies converge to show that infants start using the canonical pointing gesture with the extended index finger around their first birthdays (Butterworth & Morissette, 1996; Camaioni, Perucchini, Bellagamba, & Colonnesi, 2004; Carpenter et al., 1998). However, the frequency of pointing differs vastly at 12 months of age (Liszkowski & Tomasello, 2011). Since the frequency of infant pointing is a strong predictor for language acquisition (Colonnesi et al., 2010), a primary question is what developmental predictors may account for the differences in the frequency of 12-month-olds' pointing. Answers will be informative for assessing intervention needs in language acquisition before development goes awry, but they also elucidate theoretical perspectives on the kind of developmental process that underlies the development of social interaction.

Child-internal factors as well as socially mediating factors may predict the frequency of pointing to different degrees, and these factors may also interact in development (Demir & Küntay, 2014; Fernald, Marchman, & Hurtado, 2008). Different developmental accounts either emphasize the cognitive underpinnings of infant pointing (Tomasello, Carpenter, & Liszkowski, 2007); the role of motor development on communication and social cognition (Butterworth, 2003; Butterworth & Morissette, 1996; Campos et al., 2000); the role of caregiver behaviors in modeling or responding to infant behaviors (Bates, Camaioni, & Volterra, 1975; Brune & Woodward, 2007; Carpendale & Carpendale, 2010; Vygotsky, 1978); or interactions of any of these factors on a system level (Thelen & Smith, 1994).

Factors influencing the development of pointing frequency

Motor development

To point effectively, infants need to have a certain amount of fine-motor control to manipulate their hands into a pointing posture by extending their arms and hands, especially for index-finger pointing. The pincer grip precedes the onset of pointing and has been suggested to relate to the index-finger shape of pointing as its antagonistic posture (Butterworth, 2003; Butterworth & Morissette, 1996; Povinelli & Davis, 1994). Given that pointing requires a certain level of fine-motor control, infants' fine-motor abilities may predict how frequent infants will subsequently point. Infants with more effective control of their hand and finger movements may point more, simply because of better motor competence and fluency.

Social cognition

On more cognitively oriented accounts, another factor that could predict the frequency of pointing is the ability to understand pointing. This account entails that infants learn imitatively to point by understanding others' pointing and then adopt it. Findings show that pointing frequency is correlated with point-following frequency at 12 months (Liszkowski & Tomasello, 2011). However, the longitudinal direction is less clear. While the onset of point-following precedes pointing (Carpenter et al., 1998), and some studies find that more gaze-following, a measure akin to but less ostensive than point-following (Deák, Flom, & Pick, 2000), leads to more index-finger pointing (Matthews, Behne, Lieven, & Tomasello, 2012), there are also indications that infants get better at point-following the more they point (Leung & Rheingold, 1981).

Caregiver behavior

Because pointing is a social-communicative tool, the social environment likely shapes its development (Bates et al., 1975; Carpendale & Carpendale, 2010). One possibility is that caregiver pointing, along with infant point-following, leads to infant pointing. There is evidence for concurrent positive correlations between caregiver and infant pointing around their first birthdays (Liszkowski, Brown, Callaghan, Takada, & de Vos, 2012; Liszkowski & Tomasello, 2011). Further, a cross-cultural comparison shows that young 1-year-olds point more in cultural settings in which caregivers point more (Salomo & Liszkowski, 2013), and a training study suggests that caregivers' frequency of pointing is predictive of infants' frequency of pointing a few weeks later, albeit training with pointing-related activities had no selective effect over a control training with music-related activities (Matthews et al., 2012).

However, apart from caregivers' pointing, caregivers' responses to infants' pointing may also affect the frequency of infant pointing. Infant pointing often elicits responses from caregivers (Brooks & Meltzoff, 2008; Goldin-Meadow, Goodrich, Sauer, & Iverson, 2007; Kishimoto, Shizawa, Yasuda, Hinobayashi, & Minami, 2007; Masur, 1982; Olson & Masur, 2011). Because one goal of infant pointing is to elicit responses (Liszkowski, Carpenter, Henning, Striano, & Tomasello, 2004), responses likely support and hence should increase the frequency of infant pointing. One study shows that the frequency of gestures by 12-month-old infants increases when caregivers respond to these temporally contingently (Miller & Lossia, 2013). However, it is less clear what aspects of a response matter. While responses are typically temporarily contingent, not every caregiver response appears relevant to infants' points.

By relevance of caregiver responses to infant gestures, we mean whether the response is about infants' referent. Given that infants' goal of pointing is to share a referent, this goal is achieved once the communicative partner acknowledges in her response that she shares the referent. Achieving the communicative goal should thus support using the behavior on further occasions. In support, a correlational study (Miller & Gros-Louis, 2013) showed that caregiver responses that did not follow in on the attentional focus of infants aged 13–16 months reduced infants' concurrent frequency of gestures and gesture-vocal combinations. Another study showed that infants were more likely to gesture when mothers responded to their gestures with referential language while they were less likely to gesture when mothers responded with

regulatory language (Kuchirko, Tafuro, & Tamis-LeMonda, 2017). Likewise, caregivers' comments or actions on objects other than the target of infants' points at 10–13 months were negatively related with the improvement in infants' gesture scores from 10–13 to 15 months as measured by the MCDI questionnaire (Wu & Gros-Louis, 2014). Further corroborating evidence comes from experimental studies which demonstrate that 12-month-old infants decreased their pointing frequency across trials when adults responded temporally contingently, but never about the referent, compared to when they did refer to infants' referents (Liszkowski, Carpenter, & Tomasello, 2007; Liszkowski et al., 2004). Caregivers' responses, specifically their referential uptake, may thus play an important role in boosting infant pointing. Currently, however, it is not known whether caregiver responsiveness has also a longitudinal effect and can account for emerging differences in infants' frequency of pointing.

Systems-level interactions

Another question concerns the interaction between caregiver- and child-level factors (see Demir & Küntay, 2014; Fernald et al., 2008). Of specific interest here is that infants point with different hand shapes ranging from open hand to extended index finger, and they sometimes do and sometimes do not accompany their pointing with vocalizations (Liszkowski & Tomasello, 2011). Caregivers may vary in their attribution of communicative intent and hence in the amount and type of responses depending on the kind of infant pointing and its act-accompanying features.

The current study

To address child-level and caregiver-level factors, and how they may interact in development, we adopted a longitudinal approach and observed caregivers and their infants at 10 and 12 months in a semi-natural setting previously shown to elicit pointing (Liszkowski & Tomasello, 2011; Liszkowski et al., 2012; Lüke et al., 2017). We analyzed infants' and caregivers' points, and caregivers' verbal and nonverbal responses. In Study 1, we looked for predictors of infants' pointing frequency at 12 months of age. Therefore, we also tested for infants' point-following and fine-motor skills in experimental settings. In Study 2, we tested whether specific aspects of infant pointing would be predictive of caregiver responses to infant pointing.

STUDY 1

We tested whether infants' fine-motor and point-following skills at the age of 10 months predict their later pointing frequency at 12 months; whether caregivers' pointing frequency and their responsiveness toward infant pointing at 10 months predict infant pointing frequency at 12 months; and whether any of the factors would be a better predictor than others, controlling for infant pointing frequency at 10 months. Based on the reviewed literature, we expected that both infant and caregiver factors at 10 months would be positively related to infants' pointing frequency at 12 months and that caregiver responses to infants' early points should play a pivotal role in fostering the behavior.

Method

Participants

Thirty-five infant–caregiver dyads (15 female infants) participated in this study when infants were 10 and 12 months old. The mean age of infants at the first visit was 324.97 days (range: 309–347, *SD* = 8.79) and at the second visit 382.34 days (range: 369–398, *SD* = 7.81). The mean age of mothers was 31 (range: 20–42, *SD* = 6). All infants were full term and typically developing. All the families were living in Istanbul (a metropolitan urban center in Turkey) at the time of data collection. All caregivers spoke only Turkish. Twenty caregivers (10 female infants) had at least 15 years of formal education and were categorized as high-educated; the remaining 15 caregivers (6 female infants) had a maximum of 8 years of formal education and were categorized as low-educated.

For both Study 1 and Study 2, the participants were recruited from local health centers and from the database of the Language and Communication Development Lab (LCDL) at Koç University. All participants were debriefed after completion of the study. In the end of the study, infants were given a small gift for their participation. The studies were approved by the Koç University committee on Human Research and conducted in accordance with the Declaration of Helsinki with written informed consent obtained from a parent for each child before the study.

General procedure

Each infant–caregiver dyad first completed the *Decorated Room* procedure. The order of the two tasks of *Point Following* and *Mullen Scales of Early Learning* was counterbalanced, but the same infant received the same order of tasks at two time points. All tests were carried out in the LCDL at Koç University. Except for the *Decorated Room* procedure, all the tasks were carried out in the same testing room where the infants sat on their caregiver's lap at a table facing the experimenter. The entire testing session was videotaped for further analysis. All reliability assessments were made by coding at least 20% of the dataset by the first or the second author and a naïve coder.

The decorated room paradigm

To naturally elicit pointing behavior from infants and their caregivers, various stimuli were placed on the walls following the standard "decorated room" setup (Liszkowski et al., 2012). The items used for the purposes of decoration were the same 19 items, with the addition of a local cup, that were used by Liszkowski et al. (2012). Stimuli were kept out of reach with rope barriers placed 40 cm away from the walls to reduce caregivers' and infants' tendency to play with or touch the items.

Caregivers were asked to carry their infants on their hips (to permit the dyads to engage in eye contact) as they moved around in the room for 5 min. They were instructed to explore the room together with their infants as they wished without touching the items on the walls.

Infant and caregiver pointing. The transcription and coding of the data were performed using the ELAN software (Sloetjes & Wittenburg, 2008). Infants' and

caregivers' pointing were coded following Liszkowski and Tomasello (2011). The coding of a pointing gesture started when the person extended the arm with the whole hand or the index finger toward an item or a location and ended when she retracted the arm at least halfway. Whenever there was a switch of referents without the lowering or retracting of the pointing arm, multiple points were coded. Infants were further categorized as pointers if they pointed at least once at a given time point and nonpointers if they did not point at all. The inter-rater agreement between the coders was 87% for identifying infants' pointing (Cohen's Kappa = .78) and 95% for identifying caregivers' pointing (Cohen's Kappa = .72).

Caregiver responses to infant pointing. Following Wu and Gros-Louis (2014), caregivers' verbal and/or nonverbal behaviors that were shown during or within the 2-sec following the infants' points were annotated as caregiver responses. Caregiver responses were consequently categorized as verbal only when the caregivers gave merely a verbal response; nonverbal only when they gave merely a nonverbal response; verbal + nonverbal when they combined a verbal and a nonverbal response; and no response when they did not show any behavior. All meaningful utterances and vocalizations that had an identifiable meaning like a surprise indication such as "Oh!" or affirmation such as "Uh-huh" were coded as verbal responses. Nonverbal responses that were coded consisted of (1) Approaching (i.e., when the caregiver moved toward an object or a specific direction), (2) gaze checking (i.e., when the caregiver engaged in joint attention with the infant by looking at him/her and an object, (3) pointing (i.e., when the caregiver pointed to an object or a specific direction), (4) imitation of infant vocalization (i.e., when the caregiver imitated the infant's vocalization) and (5) laughing (i.e., when the caregiver laughed or giggled).

Relevance of caregiver responses. Each response, verbal, nonverbal or verbal + nonverbal, was later coded as relevant or nonrelevant depending on whether or not the response was about the referent the infant pointed at. We identified the referents of each of the points by the infants. The referents of infants' points were identified by the first author after obtaining an inter-rater reliability of 95% (Cohen's Kappa = .94).

The relevance of caregiver verbal responses was coded based on the referential relevance of the caregivers' first utterance or verbalization to the target of infants' points. For example, if the infant pointed at the ball and the caregiver said something about the ball such as "It is a ball," the verbal response was coded as relevant. However, the presence of the label "ball" was not a necessary criterion for the response to be coded as relevant. For verbal responses that did not include an explicit label for the referent such as "Oh, it is nice" or "We can play with it later," whether that response was referring to the target item of the infant's pointing or not was decided based on the nonverbal cues such as the caregiver's gaze or posture relative to the object. The relevance of the nonverbal behaviors was similarly coded with regard to the target of infants' points (see Table 1).

All caregiver responses were coded on the type of response and relevance. The inter-rater reliability was 89.3% for the type of response (Cohen's Kappa = .84) and 97.1% for relevance (Cohen's Kappa = .86).

Response types consisting of verbal only, nonverbal only, verbal + nonverbal and no response were calculated as percentages by dividing the number of their occurrence

TABLE 1
Relevance of Nonverbal Responses

Nonverbal responses	*Coded relevant if*
Approaching	The object or direction caregiver moves toward matches with the infant's pointing direction
Gaze Checking	The object caregiver looks at matches with the infant's pointing direction
Pointing	The object caregiver points to matches with the infant's pointing direction
Imitation of vocalization	While simultaneously her body is oriented toward the object infant pointed at
Laughing	While simultaneously her body is oriented toward the object infant pointed at

to the total number of infant points. An overall measure of responsiveness was obtained for each infant by dividing the number of infant points that received any response (all codes except no response) to the total number of infant points. In addition, regardless of the response type, a measure of relevant responsiveness was obtained by dividing the number of infant points that received a relevant response (either relevant verbal only, relevant nonverbal only or relevant verbal + nonverbal; but not no response) to the total number of infant points.

Fine-motor subscale of Mullen scales of early learning (MSEL)

The fine-motor subscale of MSEL (Mullen, 1995) was administered to assess infants' capacity of unilateral and bilateral manipulation of objects. There was a total of 30 items in this subscale but only items from 7 to 15 were administered considering our age range. Unilateral manipulation items consisted of fine-motor actions such as grasping a block or picking up a flat plastic circle with a pincer grip; while bilateral manipulation items were those such as hitting two blocks horizontally to each other or transferring blocks from one hand to the other. If infants did not demonstrate the correct action in three consecutive items, the assessment was terminated.

The range of total scores was between 0 and 12. The main experimenter scored infants' behaviors online, a second naïve coder coded from the videos of the testing session later. The inter-rater reliability was 88% (Cohen's Kappa = .78). We excluded one infant (male) at 10 months and two infants (two males) at 12 months from the analyses due to fussiness.

Point-following task

This task was adapted from Mundy et al. (2003). Four different animal stickers with a size of 31 × 31 cm were placed on 50 × 70 cm posters of different colors. Two posters were placed on the wall at 60 degrees from the infants' midline to their left and right, which were within their view. The remaining two posters were placed on the wall at 150 degrees from the infants' midline to their left and right behind, which were out of their view (i.e., behind trials).

After the experimenter attracted infants' attention, she looked at only one poster at a time by orienting her entire torso toward it and then pointed to the target poster. While pointing the experimenter said: "(Infant's name) (4 sec of pause) Oh that's nice!" After each pointing trial, the experimenter uttered a sentence related to the poster (e.g.,

"There's Mickey, did you see Mickey?") for confirming that the infants turned and saw the poster or for further engaging them with the poster if they did not turn.

The main experimenter and a naïve coder coded infants' direction of gaze and head for the four pointing trials from the video recordings. The infants received a score of 1 if they correctly followed the pointing toward its referent and 0 if not. For the behind trials, infants were given a score of 1 only when they turned their head more than 90 degrees toward the target. We excluded trials in which there was a caregiver error (e.g., the caregiver pointed to the target poster while the experimenter was pointing for the infant or the caregiver adjusted the body position of her infant for him to better see right or left behind items), or the infant was fussy.

The inter-rater agreement was 94% for identifying correct looks (Cohen's Kappa = .89). The point-following score was calculated as a percentage by dividing the total score to the total number of trials (i.e., 4-number of excluded trials). One infant (male) at 10 months and three infants (males) at 12 months had one trial excluded each due to caregiver error; one infant (female) at 10 months had two trials excluded due to fussiness. Additionally, two infants (males) could not be tested at all at 10 months due to fussiness.

Results

No significant sex or caregiver education differences were found in any of our measures of infants' and caregivers' behaviors; all analyses were collapsed across gender and caregiver education. For data that were not normally distributed, nonparametric tests were used for the correlations and mean comparison analyses, that is Spearman's rank order and Wilcoxon signed rank/Mann–Whitney tests, respectively. Because not all infants provided equal amount of data for all our measures, we first report individual relations between our predictors and infant pointing frequency; and we then assess the best predictor in an overall regression model based on a common set of infants.

Infant and caregiver pointing

Ten infants (29%) did not point at 10 months, and five infants (14%) did not point at 12 months (see Figure 1). Infants increased the total frequency of their pointing from 10 months ($M = 6.09$, $SD = 8.53$) to 12 months ($M = 10.77$, $SD = 8.43$), $Z = 2.83$, $p < .01$. There was a significant positive correlation between infants' frequency of pointing at 10 and 12 months, r_s (33) = .46, $p < .01$.

Caregivers pointed equally frequently when their infants were 10 months ($M = 17.63$, $SD = 11.02$) and 12 months old ($M = 16.66$, $SD = 10.88$), $p > .05$. There was a significant positive correlation between caregivers' frequency of pointing at 10 and 12 months, r_s (33) = .57, $p < .001$. There were no significant intercorrelations between infants' and caregivers' pointing frequency at any of the time points. However, at 10 months, caregivers of infants who were pointers pointed significantly more ($M = 20.16$, $SD = 10.76$) than caregivers of nonpointers ($M = 11.30$, $SD = 9.36$), $Z = -2.51$, $p < .05$.

Fine-motor scores

There was a significant increase in infants' fine-motor scores from 10 months ($M = 8.09$, $SD = 1.91$) to 12 months ($M = 9.30$, $SD = 1.31$), $Z = 2.89$, $p < .01$ (see

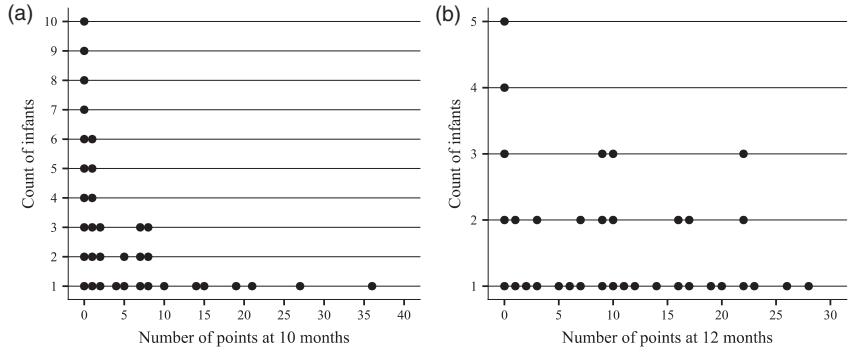

Figure 1 Frequency dot plots of infants' pointing frequency at 10 months (a) and 12 months (b).

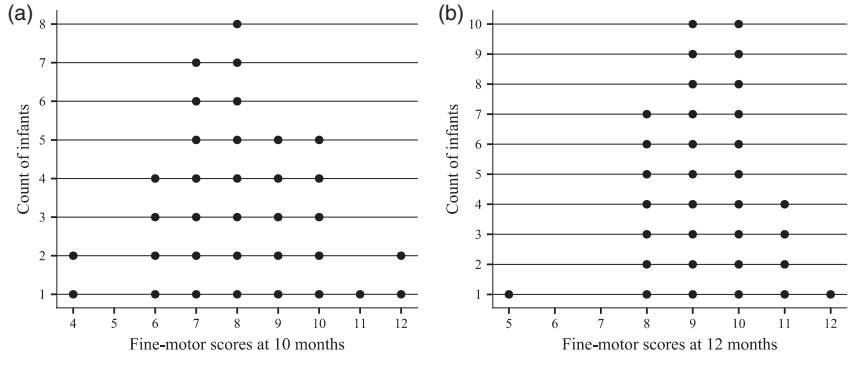

Figure 2 Frequency dot plots of infants' fine-motor scores at 10 months (a) and 12 months (b).

Figure 2 for distribution of scores). All intercorrelations were nonsignificant ($p > .05$) between infants' fine-motor scores and pointing frequencies at 10 and 12 months.

Point-following scores

Infants' point-following scores significantly increased from 10 months ($M = .32$, $SD = .27$) to 12 months ($M = .45$, $SD = .28$), $Z = -2.05$, $p < .05$, and there was a significant positive correlation between their scores at 10 and 12 months, r_s (31) = .36, $p < .05$ (see Figure 3 for distribution of scores). Point-following score at 10 months was not correlated with pointing frequency at 12 months; however, pointing frequency at 10 months was significantly correlated with point-following scores at 12 months, r_s (33) = .46, $p < .01$.

Caregiver responses

Caregivers were equally responsive to their infants' points at 10 and 12 months. They responded to 86% of their infants' points at 10 months (69% relevant and 17% nonrelevant) and to 89% of their points at 12 months (74% relevant and 15% nonrelevant). There was a significant positive correlation between the proportion of points that received nonrelevant responses by caregivers at 10 and 12 months, r_s (21) = .46,

$p < .05$. There were no significant differences in the distribution of responses between 10 and 12 months (see Figure 4) and no correlations of either response type across the two time points.

The proportion of relevant caregiver responses at 10 months correlated positively with infants' pointing frequency at 12 months, r_s (23) = .66, $p < .001$; while the proportion of nonrelevant responses correlated negatively with pointing frequency at 12 months, $r(23) = -.41$, $p < .05$. Moreover, the proportion of no responses at 10 months correlated negatively with pointing frequency at 12 months, $r(23) = -.45$, $p < .05$. Regarding the modality of response, the proportion of verbal + nonverbal responses both at 10 and 12 months correlated with pointing frequency at 12 months, respectively, r_s (23) = .49, $p < .05$; r_s (28) = .46, $p < .05$. Furthermore, pointing frequency at 10 months was positively correlated with the proportion of verbal + nonverbal responses at 12 months (r_s (28) = .57, $p < .01$), indicating a bidirectional relation between infant pointing and caregivers' bimodal responses. This was further supported by a negative correlation between infants' pointing frequency at 10 months and the proportion of verbal alone responses at 12 months, r_s (28) = −.40, $p < .05$.

Predicting infants' pointing frequency at 12 months

We ran a hierarchical linear regression analysis to analyze what contributed to the prediction of infants' pointing frequency at 12 months. The independent variables at 10 months were infants' pointing frequency (as a control measure), infants' fine-motor scores, infants' point-following scores, caregivers' pointing frequency and the proportion of relevant caregiver responses. At 10 months of age, 10 infants (4 females) did not point at all, 1 infant's (male) point-following score was missing, and 1 infant's (male) both point-following and fine-motor scores were missing. Therefore, the analysis was run with a total of 23 infants. We carried out arcsine transformations of the point-following and the relevant caregiver response scores, which were proportion values. Normality and homoscedasticity assumptions were not met for the pointing frequency at 10 months, as we had many infants who did not yet point at this age. To circumvent this problem, we did a log transformation by first adding 1 to the raw pointing frequency values.

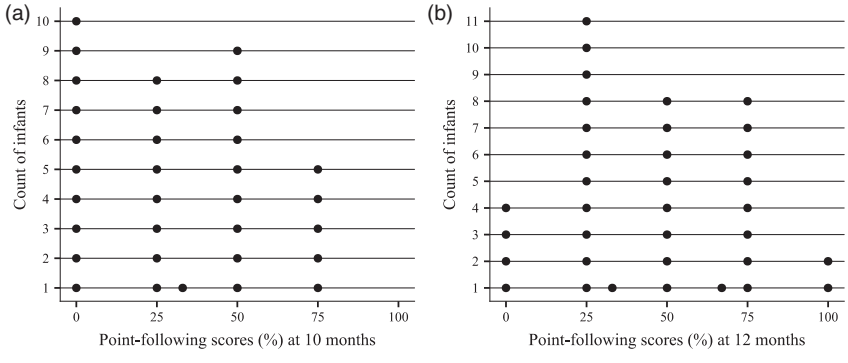

Figure 3 Frequency dot plots of infants' point-following scores in percentages at 10 months (a) and 12 months (b).

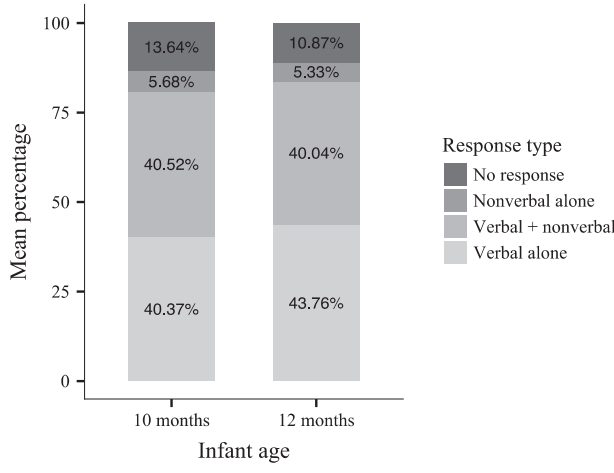

Figure 4 Bar plots of the caregiver response types at 10 and 12 months.

We first entered infants' pointing frequency at 10 months as the control variable into the regression. As hypothesized we consecutively entered the infant-driven variables of fine-motor and point-following scores at 10 months in two steps into the model. We then entered the caregiver pointing frequency and proportion of relevant caregiver responses at 10 months at the fourth and fifth step, respectively. Intercorrelations between the variables are given in Table 2, and the hierarchical regression results are given in Table 3. The results showed that neither infants' prior pointing frequency nor the infant-driven factors provided a significant contribution to the model at steps 1 through 3. Among the caregiver-mediated factors, caregiver pointing frequency was not found to be a significant predictor either and the model was not significant at step 4. However, when the proportion of relevant caregiver responses were entered at step 5, there was a significant F change and the model became significant ($F(5, 17) = 4.012$, $p < .05$), explaining 41% (adjusted R^2 at step 5 = .41) of the variance in infants' pointing frequency at 12 months.

To test whether any response, or just the relevant responses, had an effect on infant pointing at 12 months, we ran an identical hierarchical regression analysis with relevant caregiver responsiveness replaced by overall caregiver responsiveness. Again,

TABLE 2
Intercorrelations Between the Variables Entered into the Hierarchical Regression Predicting Infant Pointing Frequency at 12 Months ($N = 23$)

Variables	*1*	*2*	*3*	*4*	*5*	*6*
1. Infant pointing frequency at 12 m	1					
2. Infant pointing frequency at 10 m	.276	1				
3. Infant fine-motor scores at 10 m	.088	−.002	1			
4. Infant point-following scores at 10 m	.255	.275	.235	1		
5. Caregiver pointing frequency at 10 m	−.112	−.201	.065	.147	1	
6. Relevant caregiver responsiveness 10 m	.697*	.120	.143	.118	−.146	1

Note. *$p < .001$.

TABLE 3
Hierarchical Regression Analysis Predicting Infant Pointing Frequency at 12 Months (N = 23)

	β	t	*Sig.*	R^2	ΔR^2	F for ΔR^2
Step 1				.076	.076	1.74
Infant pointing frequency at 10 m	.276	1.31	.20			
Step 2				.084	.008	.171
Infant pointing frequency at 10 m	.277	1.29	.21			
Infant fine-motor scores at 10 m	.088	.413	.68			
Step 3				.113	.029	.619
Infant pointing frequency at 10 m	.226	1.01	.33			
Infant fine-motor scores at 10 m	.046	.204	.84			
Infant point-following scores at 10 m	.182	.787	.44			
Step 4				.123	.010	.208
Infant pointing frequency at 10 m	.199	.837	.41			
Infant fine-motor scores at 10 m	.047	.207	.84			
Infant point-following scores at 10 m	.205	.847	.41			
Caregiver pointing frequency at 10 m	−.105	−.456	.65			
Step 5				.541	.418	15.49*
Infant pointing frequency at 10 m	.157	.885	.39			
Infant fine-motor scores at 10 m	−.040	−.236	.82			
Infant point-following scores at 10 m	.143	.791	.44			
Caregiver pointing frequency at 10 m	−.001	−.008	.99			
Relevant caregiver responsiveness at 10 m	.667	3.94	.001*			

Notes. The β weights are the standardized coefficients at each step. *$p < .001$.

caregiver responsiveness appeared as the only significant predictor yielding a significant, albeit smaller, F change ($\Delta R^2 = .24$, $\Delta F = 6.27$, $p < .05$). However, the final model was not significant, $F(5, 17) = 1.77$, $p = .17$, revealing that caregiver responsiveness was not a significant predictor, but relevant caregiver responsiveness was.

Discussion

Infants' pointing frequency, fine-motor scores, and point-following scores increased from 10 to 12 months while the rate of caregivers' pointing and responses to infants' points remained the same. Caregiver-level factors, but not child-level factors, best predicted pointing frequency at 12 months.

Fine-motor skills were not predictive of pointing frequency. Infants have sufficient motor control to extend their arms and index fingers as early as 3 months of age (Fogel & Hannan, 1985; Masataka, 2003), and while fine-motor skills are necessary to form a pointing gesture, our results suggest that these skills are not related to how often infants then use the gesture once it has emerged. How often they choose to point might rely more on other factors such as infants' motivation to produce or understand the communicative function of a point.

Infant point-following, however, was not predictive of later pointing frequency either, in contrast to Matthews et al.'s (2012) finding of a positive relation between early gaze-following and later pointing. One possible explanation is that our point-following task was more complex than that in Matthews et al. (2012) because in two of four trials it required infants to look behind their visual field, an ability suggested to be slightly more complex than just looking to the lateral side (Butterworth & Cochran,

1980; Butterworth & Jarrett, 1991; but see Deák et al., 2000). However, again, it is also possible that point-following is related to the acquisition of the ability to direct others' attention (Carpenter et al., 1998), but not to how often infants will then use attention-directing behaviors. Interestingly, we found a reverse positive longitudinal relation between early pointing and later point-following. This relation may be mediated by caregiver pointing, because parents of pointers at 10 months pointed more than parents of nonpointers at 10 months, thus providing infants with more opportunities to exercise their point-following, perhaps especially in "joint pointing" sequences (Liszkowski et al., 2012; "pointing strings", Murphy, 1978).

Caregivers' pointing and responses to infants' points did not change from 10 to 12 months. This suggests that caregivers do not simply follow, or react to infants' pointing, because then caregivers should have shown less of the behaviors at 10 months of age. Rather, parents provide a scaffold to which infants then adopt. Of particular interest here is our finding that only the relevant responses, not overall responsiveness, predicted infants' pointing frequency at 12 months. This suggests that infants are actively socialized into the practice of pointing together (see Bruner, 1983). Once infants point, its' usage in terms of frequency is then predicted to a large extent by whether it achieves the communicative goal of sharing a referent.

Because caregiver responses are crucial in achieving the goal of shared reference, a follow-up question to our current findings is whether certain characteristics of infant pointing are more likely to elicit relevant responses by caregivers. For example, it is possible that caregivers attribute communicative intent more readily given certain accompanying characteristics. We addressed this question in Study 2 and examined whether the shape of infants' hands, and the presence of vocalizations, would differentially influence caregiver responses.

STUDY 2

Caregivers' responses to their infants' pointing are likely influenced by certain qualitative characteristics of infants' points. One such characteristic is whether infants do or do not vocalize when they point. Some findings suggest that adults' rate of verbal responses are similar when infants gesture with or without accompanying vocalizations (Kishimoto et al., 2007; Wu & Gros-Louis, 2015), while another study (Miller & Lossia, 2013) suggests that adults' rate of responses are higher when infants gesture without vocalizations. On the other hand, given that infants increase their vocalizations when their communicative goal of pointing is not met (Gros-Louis & Wu, 2012; Liszkowski, Albrecht, Carpenter, & Tomasello, 2008), infants seem to expect that a caregiver is more likely to respond to their points when they use their voices as an additional communicative source.

Another characteristic of interest is the hand shape of the pointing gesture. Whole-hand pointing is more often associated with an imperative motive and index-finger pointing with a declarative motive (Franco & Butterworth, 1996; Grünloh & Liszkowski, 2015). If caregivers perceive their infants' index-finger pointing to be declarative and whole-hand pointing to be imperative, they might be more likely to give referent-related responses to index-finger pointing to meet the attention-sharing motive of their infants. Infants' index-finger pointing is also accompanied by vocalization to a greater extent compared to whole-hand pointing (Liszkowski & Tomasello, 2011).

Hence, the hand shape of the infants' pointing gestures and whether they vocalize or not while pointing might interact in relation to caregivers' responses.

We asked whether caregiver responses differ depending on qualitative characteristics of infants' pointing. Specifically, we hypothesized that the index-finger points (as opposed to whole-hand points) and points with an accompanying vocalization (as opposed to ones without) would elicit higher responsiveness and a higher rate of relevant responses from caregivers, because caregivers would perceive these as more communicative. In addition, in a more exploratory vein, we also looked at whether caregivers would respond with different types of speech acts depending on the characteristics of infants' points. For example, caregivers may interpret whole-hand points rather as invitations to act on something and index-finger points to elaborate or comment on something (see Marcos, 1991; Marcos, Ryckebusch, & Rabain-Jamin, 2003; Masur, 1982; Olson & Masur, 2011).

Method

Participants

An additional 14 infant–caregiver dyads (8 female infants) were tested in the decorated room paradigm (but not for the additional measures of Study 1) when the infants were 10 and 12 months old, resulting in a final sample of 49 infant–caregiver dyads (23 female infants). The mean age of infants at the first visit was 323.14 days (range: 303–347, $SD = 9.1$) and at the second visit 380.94 days (range: 369–398, $SD = 7.85$). The mean age of mothers was 31 (range: 20–42, $SD = 5$). All infants were full term and typically developing. All the families were living in Istanbul (a metropolitan urban center in Turkey) at the time of data collection and spoke only Turkish except 2 who spoke both Turkish and Kurdish. Thirty-two caregivers were high-educated and 17 were low-educated.

Procedure

Infants and caregivers were tested on several tasks as part of a bigger project conducted in the LCDL at Koç University. For this particular study, only data from the decorated room paradigm were used. The same procedure of Study 1 was used except that the room was slightly smaller and there were no rope barriers. The transcriptions and the coding procedures were the same as Study 1 except that the infant pointing was additionally coded according to the hand shape of the pointing and whether pointing was accompanied by vocalization. Also, verbal responses of caregivers were categorized into speech acts.

Following Liszkowski and Tomasello (2011), index-finger points were coded when the index finger was clearly more extended than other fingers toward a referent while whole-hand points were coded when the flat hand was extended toward a referent. Whole-hand points were distinguished from reaching behaviors such that if the infant extended the flat hand toward a referent while clearly leaning forwards, it was considered reaching and was not coded.

Following Wu and Gros-Louis (2015), accompanying infant vocalizations were coded within a window of 2 sec prior and following their pointing. Any sound infants

made were considered to be vocalizations, except vegetative ones like coughs, negative vocalizations like cries, and effort sounds like grunts.

Caregivers' first utterances that followed their infants' points within a 2-sec window were categorized into speech acts of question, naming, comment, prohibitive, affirmative, play, and directive based on Wu and Gros-Louis (2015). Speech act categories were mutually exclusive. Verbal responses that implied more than one speech act were coded according to their main purpose. For example, the verbal response "Look at that ball" was coded as directive only, or "What is that, is that a ball?" was coded as question only, as the main purpose of these utterances was not to name the object but to direct the child's attention to the object and to ask a question, respectively. All verbal responses caregivers provided fit into one of the seven categories below (Table 4).

The inter-rater agreement between the coders on the additional 14 infants was 96.5% for identifying infants' pointing (Cohen's Kappa = .85); 95.1% for identifying caregivers' pointing (Cohen's Kappa = .84); 96.8% for identifying the hand shape of infants' pointing (Cohen's Kappa = .94); 93.8% for identifying whether vocalizations accompanied infants' pointing (Cohen's Kappa = .88); and 95% for the speech act categorization of caregiver verbal responses (Cohen's Kappa = .91).

Results

Infant points and hand shape

Out of the total 49 infants, four infants (one female) pointed at neither 10 nor 12 months. Two infants (one female) pointed only at 10 months; seven infants (three females) pointed only at 12 months. Hence, at 10 months, the total number of infants who pointed was 38 (19 females) and the total number of points observed was 325. At 12 months, the total number of infants who pointed was 43 (21 females) and the total number of points observed was 652. Twenty infants (nine females) at 10 months and 37 infants (17 females) at 12 months pointed at least once with their index finger.

Infants increased both their index-finger points ($M = 2.45$, $SD = 5.50$; $M = 6.65$, $SD = 7.56$, for 10 and 12 months, respectively), $Z = -3.86$, $p < .001$; and whole-hand points ($M = 4.18$, $SD = 5.71$; $M = 6.61$, $SD = 7.17$, for 10 and 12 months, respectively), $Z = -2.27$, $p < .05$. Thirty percent ($SD = .36$) of infants' total points at

TABLE 4
Speech Acts Coding Scheme

Speech acts	*Definition*	*Example*
Question	Asking any kind of question (including rhetorical questions)	Which one did we like? Do you want those?
Naming	Explicitly naming an object	A ball. That one is a butterfly.
Comment	Making a comment on something	We liked the sun. That's really nice.
Prohibitive	Expresses that the infant or both of them are not allowed to do something	We cannot take it. No, no, no!
Affirmative	Praising or acknowledging the child	Uh-huh. Yes, right.
Play	Singing or making sound effects	Vroom-vroom. Beep-beep.
Directive	Attracting the child's attention or directing the child to do something	Look at that. Blow at the pinwheel.

10 months were index-finger points which increased to 48% (SD = .34) at 12 months, $Z = -2.31$, $p < .05$. Thirty-two percent (SD = .36) of infants' total points at 10 months were accompanied by vocalization; this rate increased to 52% (SD = .30) at 12 months, $Z = -2.73$, $p < .01$. There was a correlation between the frequency of infants' index-finger pointing at 10 and 12 months (r_s (47) = .37, $p < .01$) and a correlation between the frequency of infants' whole-hand pointing at 10 and 12 months (r_s (47) = .40, $p < .01$). The percentage of points that were accompanied by vocalization at 10 and 12 months were correlated, r_s (34) = .34, $p < .05$, as well as the percentage of points with the index-finger at 10 and 12 months, r_s (34) = .36, $p < .05$.

Caregivers' responses in relation to infants' point characteristics

In order to examine whether caregiver responses differed depending on the hand shape of infants' pointing or depending on whether vocalization accompanies pointing or not, we ran generalized linear mixed models (GLMM) using "lme4" package and "glmer" function in R software (Bates, Mächler, Bolker, & Walker, 2014). Hand shape and accompaniment by vocalization were entered as fixed effects, and caregiver–infant pairs were entered as a random effect letting intercepts to vary. We only let the intercepts vary rather than both the intercepts and the slope because the former model proved to be more parsimonious in all our model comparisons. All variables in these analyses were binary with hand shape referring to index-finger or whole-hand points, accompaniment by vocalization referring to the presence or absence of an infant vocalization along with points, and caregiver responses referring to the presence or absence of a caregiver response, a relevant caregiver response, or a specific speech act. Index-finger points and the presence of the remaining variables were dummy coded as 1, whereas whole-hand points and the absence of the remaining variables were dummy coded as 0.

Because there were only half as many points observed at 10 months compared to 12 months, the analyses on only 10-month-olds' data turned out to be underpowered and some of the mixed-effects models failed to converge due to low sample size. Given our findings of Study 1, which revealed that the caregiver responses remained similar both at 10 and 12 months, we collapsed data of 10 and 12 months, yielding a total of 977 pointing gestures from 45 infants.

Before analyzing whether receiving a response or a relevant response from caregivers was influenced by the hand shape or presence of accompanying vocalizations, we first checked whether hand shape was related to accompanying vocalizations. To do so, we regressed the presence of accompanying vocalizations on hand shape in a mixed logistic regression analysis. Hand shape was indeed related to accompanying vocalizations, x^2 (1) = 10.18, $p < .01$. The odds of accompaniment by vocalization was 1.68 times greater for index-finger points than whole-hand points, $\beta = .52$, $z = 3.18$, $p < .01$.

As the hand shape and accompaniment by vocalization covaried, we entered these two variables separately when we regressed caregiver responses on them. Hand shape was neither a significant predictor for caregivers' overall responsiveness (x^2 (1) = 2.14, $p = .14$) nor for relevant responsiveness (x^2 (1) = 1.13, $p = .29$). However, vocal accompaniment was a significant predictor both for caregivers' overall responsiveness (x^2 (1) = 5.12, $p < .05$) and for relevant responsiveness (x^2 (1) = 15.57, $p < .001$). The odds of receiving a response to points that were accompanied by vocalizations was

TABLE 5
Mixed Logistic Regressions Predicting (i) Responsiveness and (ii) Relevant Responsiveness from Hand Shape and Accsompaniment by Vocalization

	β (SE)		*Z*		*Sig.*		*Exp (β)*	
	i	*ii*	*i*	*ii*	*i*	*ii*	*i*	*ii*
Hand shape	−.384 (.26)	−.182 (.17)	−1.45	−1.07	.146	.284	1.47	1.20
Accompaniment by vocalization	.574 (.26)	.663 (.17)	2.24	3.91	.025*	.000**	1.78	1.94

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

1.78 times greater, and for a relevant response 1.94 times greater, than for points that were not accompanied by vocalizations (see Table 5).

To test whether the effects of pointing with vocalizations on caregiver responses was stronger for index-finger than whole-hand pointing, we ran a further mixed logistic regression analyses on all points with vocalizations. There were no significant effects. Thus, whether the points with vocalizations had the index-finger shape or the whole-hand shape did not make a difference to how caregivers responded. We ran the same analyses on all points without vocalizations. Whether these were with the index finger or the whole hand had no effect on overall caregiver responsiveness. However, caregiver relevant responses were 1.82 times more likely for whole-hand points without vocalization than index-finger points without vocalization, $\beta = -0.6$, $p < .05$.

Next, we examined speech acts. For each infant, we first calculated the percentages of each speech act by dividing the number of the infant's points that received that type of speech act to the total number of his points. The most common speech act caregivers used to respond to their infants' pointing at both ages was "question," and there were no significant age differences for any of the categories (see Figure 5). We then tested whether speech acts by caregivers were more or less likely depending on the hand shape or the presence of an accompanying vocalization of infant pointing. Caregivers were more likely to give prohibitive responses to infants' whole-hand points compared to

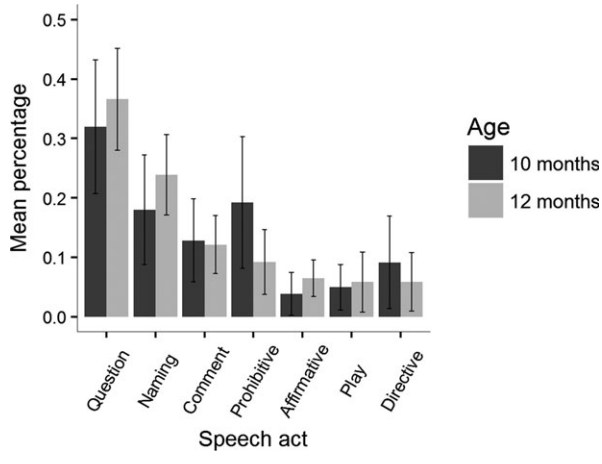

Figure 5 Mean percentages of speech acts of caregiver responses at 10 and 12 months (error bars represent 95% CI).

index-finger points ($z = -3.55$, $\beta = -1.27$, exp (β) = 3.56, $p < .001$), as well as to infants' points without an accompanying vocalization compared to ones with it ($z = -3.28$, $\beta = -1.01$, exp (β) = 2.75, $p < .01$). In addition, caregivers were more likely to ask questions as a response to infants' points with an accompanying vocalization than to ones without accompanying vocalizations ($z = 2.95$, $\beta = .49$, exp (β) = 1.63, $p < .01$).

Discussion

Infants increased both the frequency of their index-finger and of their whole-hand pointing from 10 to 12 months, along with the vocalizations that accompany their points and the relative use of index-finger pointing over whole-hand pointing. Thus, there was not only a quantitative increase in the frequency of pointing but also a qualitative shift in communicative quality toward the more conventional hand form of pointing and the integration of the vocal modality. Points accompanied by vocalizations elicited more caregiver responses, and specifically relevant responses, while the hand shape of these points did not matter. Only when the points were not accompanied by vocalizations, did hand shape matter and caregivers provided more relevant responses when the points were whole-hand points.

One interpretation is that accompanying vocalizations make caregivers perceive infants' pointing more readily as communicative, so that they react more adequately to infants' communicative intent. An intriguing possibility that would need additional experimental support is then that infants begin to vocalize when pointing because it makes their gestural communicative attempts more successful. This would mean that caregivers' recognition of the child's communicative intent shapes the form children adopt to communicate. Our finding that caregivers do not differentiate between infants' hand forms might explain why whole-hand pointing initially also increases in frequency. Our analyses on the speech acts of caregivers' responses are informative in this respect: Points with vocalizations elicited a referential uptake on the epistemic level, mostly in the form of questions, presumably because caregivers wanted to elaborate on infants' "perspectives" on the world. Whole-hand points without vocalizations rather elicited uptake on the action level, mostly in the form of prohibitive talk, presumably because caregivers interpreted the acts as requests to obtain the referents. Perhaps because of our task instructions to not touch the objects, caregivers reacted prohibitively (e.g., "We cannot touch the ball, we can only look at it").

Some studies showed that caregivers predominantly respond to their infants' points with comments (Wu & Gros-Louis, 2014), while others suggested cultural variation and reported examples of questions as responses to points (Brown, 2011). While we think both comments and questions are indications of engaging with perspectives on the referent, it remains unknown whether the predominant response type of questions in the current study was due to the referent items, the task construal, or culture or language-specific aspects.

GENERAL DISCUSSION

The current study investigated predictors of pointing frequency at the end of the first year of life, because pointing frequency has been identified as an important predictor

for later vocabulary and language acquisition. From an applied perspective, this knowledge may contribute to enhance intervention programs in the acquisition of language very early in development. For example, a previous training study on pointing found no effects of training when caregivers were instructed to point for their infants (Matthews et al., 2012). Based on our current results, we assume that a selective training on relevant referential responses to infants' deictic acts should be more successful. From a theoretical perspective, our findings contribute to refining our understanding of developmental process.

Theoretical accounts on the development of social interaction often focus either on social-cognitive processes enabling participation in social interaction (Tomasello, 2008), or on social-interactional experiences giving rise to social-cognitive understanding (Carpendale & Carpendale, 2010; Carpendale & Lewis, 2004). A perhaps more coherent, dialectic perspective would acknowledge that changes on one level lead to changes on the other level, with feedback and mutual dependencies on both levels. For infant pointing at 12 months of age, a rich social-cognitive and motivational basis has been identified (for an overview: Liszkowski, in press), which enables participating in meaningful interactions with shared intentionality (Tomasello et al., 2007). However, it has remained underexplored to what extent social interactional experiences in the first year of life give rise to this social-cognitive and motivational basis.

Our current findings reveal that individual child-level factors, like fine-motor skills and point-following, and individual caregiver-level factors, like caregivers' own pointing, are not as predictive as the interaction of these factors in the form of caregivers' responses to infants' points. These findings demonstrate that frequent use of pointing does not simply develop through child-level individual processes. Instead, social-interactional experiences play a pivotal role from early on. Crucially, our findings reveal that it is not any kind of social experience but specifically the relevant referential uptake of infants' earliest points, irrespective of whether these are done with the hand or the index finger. Of course, behaviorist accounts have known all along that there must be reinforcers for an increase of a given behavior, but they have never been able to predict specific ones because they are blind to the processes in the organism. In our view, if referential uptake increases the occurrence of pointing, it means that referential uptake most likely satisfies the goal of infants' behavior, which in turn must mean that even the earliest points entail some form of intentional relation toward the referent, however crude.

One limitation of the study is that we assessed pointing behavior with a paradigm specifically designed to elicit pointing. Hence, the observed pointing frequencies might overestimate and not fully represent the dyads' pointing in their everyday environments and routines (see Salomo & Liszkowski, 2013). The paradigm represents only one of the many potential contexts in which parents and their infants engage in pointing. For example, a free play context might entail more object manipulation and less pointing, or a book-reading context might entail even more pointing. Similarly, adults' responses and the communication patterns differ depending on the context (Olson & Masur, 2011; Puccini, Hassemer, Salomo, & Liszkowski, 2010). Our current paradigm created a "context-of-regard," and while we did not assess or manipulate infants' social intentions, caregivers responded according to how they interpreted their infants' pointing which presumably generalizes to what they would do in their natural environment.

All in all, the current findings reveal how pervasive interactional experience and social engagement are in shaping the very basis of pointing as the "foundational building block" (Kita, 2003) of human communication. Thus, while the shared

intentionality of infant pointing certainly is a gateway to social-interactional experiences that influence subsequent cognitive processes (Tomasello, 2014; Vygotsky, 1978), current findings suggest that it is as much a product of social-interactional experiences which transform simpler cognitive processes in ontogenetic time.

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