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PAPER

Origins of the human pointing gesture: a training study

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Abstract

Despite its importance in the development of children's skills of social cognition and communication, very little is known about the ontogenetic origins of the pointing gesture. We report a training study in which mothers gave children one month of extra daily experience with pointing as compared with a control group who had extra experience with musical activities. One hundred and two infants of 9, 10, or 11 months of age were seen at the beginning, middle, and end of this one-month period and tested for declarative pointing and gaze following. Infants' ability to point with the index finger at the end of the study was not affected by the training but was instead predicted by infants' prior ability to follow the gaze direction of an adult. The frequency with which infants pointed indexically was also affected by infant gaze following ability and, in addition, by maternal pointing frequency in free play, but not by training. In contrast, infants' ability to monitor their partner's gaze when pointing, and the frequency with which they did so, was affected by both training and maternal pointing frequency in free play. These results suggest that prior social cognitive advances, rather than adult socialization of pointing per se, determine the developmental onset of indexical pointing, but socialization processes such as imitation and adult shaping subsequently affect both infants' ability to monitor their interlocutor's gaze while they point and how frequently infants choose to point.

Introduction

Nothing is more important to human cognitive and social development than the acquisition of a conventional language. But virtually everyone who has investigated the origins of children's language development has concluded that many of the most basic elements of the process are already established in pre-linguistic gesturing, most importantly in declarative acts of reference with the pointing gesture (Bates, 1976; Colonnesi, Stams, Koster & Noom, 2010; Eilan, 2005).

We know a good bit about the developmental trajectory of pointing once it emerges at around 12 months of age (see Tomasello, Carpenter & Liszkowski, 2007, for a review). But we know surprisingly little about its origins. One problem is that, although seemingly simple, the pointing gesture actually comprises a number of distinct components. Most basically, infants' acts of pointing are underpinned by: (i) motoric prerequisites for arm extension and index finger extension toward external objects; (ii) motivational prerequisites for communicating with others in various ways (e.g. requesting things imperatively, or indicating them declaratively); and (iii) social-cognitive prerequisites for following, directing, and sharing attention with others.

A key issue for theories of the ontogenetic origins of the pointing gesture is the role of the social environment. Theories addressing this issue may be broadly divided into two groups: Spontaneous Onset accounts in which the emphasis is on the spontaneous emergence of the pointing gesture from other developmental achievements (e.g. Butterworth, 2003), and Socialization accounts in which the emphasis is on social learning processes such as imitative learning and/or the shaping of the gesture via adult reactions (e.g. Bates, Camaioni & Volterra, 1975; Carpendale & Carpendale, 2010; Cochet & Vauclair, 2010). Complexities arise because theories focus on one or another of the different components of the process and because it is possible, indeed likely, that some components emerge more or less spontaneously (where spontaneous is intended to mean without learning through imitation or direct reinforcement) whereas others are due to socialization processes – or it is even possible that the early emergence of some components is spontaneous and then further developments are due to socialization. While an intricate

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interplay of nature and nurture is to be expected (Carpendale & Lewis, 2010), there is no experimental work to pick apart this interplay and establish precisely where and to what extent socialization affects this fundamental development in human communication. To begin teasing this apart, it is useful to look at the factors involved in each of the most basic components of pointing separately.

Motoric prerequisites

Even great apes will extend their arm and open hand toward desired objects in the presence of humans, who often fetch the object for them (Leavens & Hopkins, 1998). Human infants also perform such 'open hand' pointing late in the first year of life, also to request objects. Some researchers have hypothesized that infant open hand pointing is not 'the real thing', since it does not correlate with the comprehension of indicative pointing gestures from others as does index finger pointing (Butterworth, 2003; Liszkowski & Tomasello, 2011). Nonhuman primates do not typically point with their index finger (although see Leavens, Hopkins & Bard, 2005). In contrast, human infants regularly extend their index fingers non-communicatively from very early on (Fogel & Hannan, 1985; Hannan, 1987; Masataka, 2003; Nagy, Compagne, Orvos, Pal, Molnar, Janszky, Loveland & Bardos, 2005), and indeed there is some evidence that the structure of the human hand facilitates index finger extension relative to other apes (Povinelli & Davis, 1994). It is possible that this species difference has to do with the adaptation of the human hand for a pincer grip between thumb and index finger, which other great apes do not have – and this then generalizes during ontogeny to inspecting objects by poking them with the index finger, which then generalizes to pointing (Butterworth, 2003; Gomez, 2007). Such an account is taken as support for proposals that pointing can also have a contemplative or interrogative function (Bates *et al.*, 1975; Bruner, 1983; Franco, 2005; Franco & Butterworth, 1996; Southgate, van Maanen & Csibra, 2007. It also might explain why congenitally blind children are reported not to point even though they do gesture (Iverson & Goldin Meadow, 1998).[1] Finally, it is also possible that index finger extension could be an adaptation for the pointing gesture itself.

In all, it would seem unlikely that social experience has a strong shaping effect on infants' motoric tendency to protrude their index fingers. Nonetheless, the use of the index finger for the function of communication could still be due either to imitation or social shaping. Indeed imitation is possible since pointing gestures are known to be recognized by 8 months (Gredebäck, Melinder & Daum, 2010), are produced by caregivers in particularly salient ways for young infants (Murphy & Messer, 1977; see also Brand, Baldwin & Ashburn, 2002), and tend to be comprehended before they are produced (Bruner, 1983; Camaioni, Perucchini, Bellagamba & Colonnesi, 2004). Likewise, social shaping is possible since adults respond to the infant's index finger extensions in rewarding ways (Kishimoto, Shizawa, Yasuda, Hinobayashi & Minami, 2007; Lock, Young, Service & Chandler, 1990; Masataka, 2003). However, to our knowledge, there is no work to test the causal role of pointing imitation or socialization.

Motivational prerequisites

With regard to motivation, Tomasello *et al.* (2007) proposed three motives for infants' early pointing: imperative, declarative and informative. Other theorists have also argued for an interrogative motive, where infants point to obtain information from a caregiver (Bruner, 1983; Franco, 2005; Franco & Butterworth, 1996; Southgate *et al.*, 2007). We assume that these motives are not created by socialization processes, but it is possible that they are integrated with communicative pointing by one or another process of social learning. That is, infants may learn that their goal to share attention can be realized through pointing.

For example, classic theorists beginning with Wundt (1900) and Vygotsky (1978) (see also Leung & Rheingold, 1981; Murphy & Messer, 1977) proposed that infants' motivation to point for others begins with their attempts to obtain out-of-reach objects, which adults notice and respond to by fetching the object. Reaching is thus socially shaped and ritualized into pointing. Bates *et al.* (1975) noted that this account is only aimed at imperative pointing, and cannot account for declarative pointing in which the infant simply wants to share attention to an object. It is declarative pointing that we focus on here, given its theoretical and empirical association with later language learning (Tomasello, 2008; Colonnesi *et al.*, 2010).

Bates and colleagues' account of declarative pointing relied on two developmental precursors: contemplating objects and engaging a caregiver. For example, one infant they studied, Carlotta, was observed to contemplate objects first by touching them, then by looking at them, then by pointing at them.[2] Over the same 9- to 12-month period, Carlotta made the transition from showing off (blowing raspberries), to showing an object to the caregiver, to giving an object and finally pointing

[1] Yet note that sighted infants point to things they can hear but not see, suggesting that pointing is not only produced when visually orienting to interesting stimuli (Iverson & Goldin Meadow, 1998).

[2] Carlotta's first points were assumed to be contemplative, rather than communicative, as they not involve gaze checking the interlocutor. These contemplative points included ones directed at events, such as pointing to a noise outside. It is assumed that such points were performed as a means to regulate attention toward an event or object.

at objects while alternating gaze with her interlocutor. Bates (1976) argued that by the time Carlotta referred to an object by pointing, the gesture had already been developed for the non-communicative purpose of contemplation (and that it is this original function that forms the basis of the topic/comment structure of language).

There are several other accounts similarly proposing that declarative pointing emerges when pointing for non-social contemplative purposes becomes socialized by a caregiver (Brune & Woodward, 2007; Delgado, Gomez & Sarria, 2009; Desrochers, Morisette & Ricard, 1995; Gomez, 2007; Lempert & Kinsbourne, 1985; Masur, 1983; Schaffer, 1984; Werner & Kaplan, 1963). The most recent account in this direction is that of Carpendale and Carpendale (2010), who report two new diary studies designed specifically to investigate the origins of pointing. This study provides evidence of an infant, Grey, starting to point for what appear to be non-communicative purposes. Such observations lend weight to accounts that propose that communicative pointing emerges from the socialization of non-communicative points, although experimental evidence is needed to test for a causal effect of socialization.

Social-cognitive prerequisites

With regard to social cognition, there is some debate about whether infants are pointing to direct others' attention to things (the rich view) or just to produce desired behavioral effects in others (the lean view; see Tomasello *et al.*, 2007, for a review). Assuming the richer view, the question is how infants learn to use pointing to direct another's attention. Again, the two possibilities are that (1) infants spontaneously use pointing to redirect others' attention as soon as they are able to follow gaze and engage in joint attention (Butterworth, 2003) or (2) experience with caregivers either allows infants to imitate pointing for communicative purposes or shapes an existing behavior into intentional pointing. In the latter category, Cochet and Vauclair (2010) propose that infants learn to point declaratively by imitative learning (see also Leroy, Mathiot & Morgenstern, 2009; Leung & Rheingold, 1981; Murphy & Messer, 1977; Tomasello, 1999). On this account, infants learn to direct adult attention with a pointing gesture first by comprehending that this is what others are doing when they point for the infant (or others) and then imitating the gesture when they have the same motive. Though plausible, there is almost no direct evidence for the imitation hypothesis beyond the fact that the rate of infant pointing and the rate of maternal pointing both increase in the second half of the first year, and 'the changes that occur in the frequency of maternal pointing occur 2 months before those of the infants' (Lock *et al.*, 1990, p. 50). This correlation, however, could be driven by mothers' estimations of their child's emerging abilities of comprehension. Experimental evidence is required to unpick this.[3]

Testing accounts of the ontogenetic origins of pointing

All of the empirical studies on the onset of infant pointing are descriptive or correlational in nature. This is problematic when it comes to assessing the causes of pointing onset. Parents tend to start pointing more just before their infants begin to point. Infants develop new social-cognitive abilities just before they start to point. But we cannot be certain if either change was necessary for pointing to begin. Of course this problem is well recognized, but it is difficult (both practically and ethically) to experimentally manipulate the relevant variables. Nonetheless, one key difference between Spontaneous Onset and Socialization accounts is the extent to which parent modeling of and responding to the pointing gesture is proposed to be necessary for infants to start pointing. If such socialization is necessary, then increasing parents' rate and awareness of pointing should result in infants pointing earlier. If it is not, as Spontaneous Onset accounts would suggest, then such parental changes should not affect infant pointing onset. Finally, if socialization and imitation are only involved in elaborating the pointing gesture, then our intervention might affect frequency or quality of pointing, rather than the age of onset.

In the current study, we randomly assigned parents and their 9-, 10-, or 11-month-old infants to either a pointing training condition or a control condition. Parents in the training condition were shown a number of pointing activities and asked to spend 15 minutes a day actively engaging in such activities with their infants for the duration of one month. We reasoned that this should be enough to significantly increase the frequency with which infants in the experimental condition were likely to observe pointing over the course of a month, and it would also necessarily increase parents' awareness of pointing such that they would be more likely to notice if their child pointed and would respond to them doing so. Parents in the control condition were asked to spend the same amount of time per day singing nursery rhymes and playing with musical instruments with their infants. This control activity was designed to be equally socially engaging and potentially beneficial for the development of language and communication (Bryant, Bradley,

[3] Another way infants could learn to use pointing to direct others' attention is by the kinds of social shaping processes outlined above (e.g. reaching to obtain an object is socialized into pointing to request an object; showing off in order to get adult attention is socialized into using an object to share attention). But this process implies that infants do not really understand the intentional dimensions of the process – that the pointer intends that the recipient jointly attend with her to something – and many lines of evidence suggest that they do indeed have such understanding, at least by 12 months (see Tomasello *et al.*, 2007, for a review). A viable socialization account, then, would need to propose that learning how to use pointing occurs between 9 and 12 months. Again, there are no experimental studies to test this.

Maclean & Crossland, 1989; Gerry, Unrau & Trainor, 2012; Hannon & Trainor, 2007). All infants were tested for their ability to follow gaze and to point declaratively to a distal target during three test sessions at 2-week intervals (before, during, and after intervention). Parents' pointing rate was also measured in a free play session. We were therefore able to test whether (1) a month of training, (2) parents' rate of pointing in free play and (3) infants' prior gaze following abilities had an impact on either the *ability* to point declaratively (pointing onset) or on the *frequency* and quality of pointing. Regarding quality, we assume that alternating gaze with the adult while pointing, while not absolutely necessary to establish joint attention, is a clear indication of communicative intent (although see Carpendale & Lewis, 2004, p.85, for a discussion of the debate regarding the meaning of gaze alternation). Since index finger pointing is considered the true precursor to linguistic reference, particularly when accompanied by vocalization or gaze checking, we distinguished in all analyses index finger pointing from open hand pointing.

Method

Participants

One hundred and two typically developing, full-term infants and their parents participated in this study for the full month (58 boys, 44 girls). There were 15 9-month-olds, 66 10-month-olds and 21 11-month-olds (see Table 1). Five 10-month-olds were included in this sample but did not attend the lab for visit 2. Twelve infants started the study but did not attend visit 3 and were therefore excluded along with one infant who turned out to have a developmental disorder. Over 90% of the sample was white and middle class. The majority of parents (68% of mothers, 58% of fathers) had a university degree. The majority (64%) of infants did not have any siblings. The infants were tested in two university laboratories in the UK.[4] Full parental consent was obtained for each child.

Procedure and materials

Each infant and their parent visited the university laboratory on three occasions over the span of a month. On their first visit, the dyads were randomly assigned to a pointing training condition or a music training condition. All infants took part in the same tests of gaze following and declarative pointing. Only the procedure used to introduce the parents to the training differed as a function of condition. All test sessions were video recorded.

Visit 1

Parental questionnaire and warm-up

At the beginning of the first visit, parents filled out consent forms and a questionnaire with demographic information about their family and a report of their child's communication (age-appropriate sections of the MacArthur-Bates CDI (Fenson, Dale, Reznick, Bates, Thal & Pethick, 1994) and the LUI (O'Neill, 2007)). While parents filled out these questionnaires, the infant played with the two female experimenters, E1 and E2 for at least 5 minutes of warm-up time. E1 then briefly explained the visit procedure to the parent before beginning the first test. Having done so, she said, 'The idea is basically just to see if this [=activities done in given condition] helps [child's name] understand other people communicating with him/her and even if it changes the way s/he communicates with other people – like better comprehension of other people's communication, engaging with people's eye gaze or even attempting to communicate with people themselves.'

Test of gaze following

After the warm-up, E1 conducted a short test of the infant's ability to follow her gaze to a distal object (Carpenter, Nagell & Tomasello, 1998). Two colorful smiley faces (approx 30 cm in diameter) were hung at either side of E1 at a distance of 125 cm. El and the infant both sat on the floor facing each other (90 cm apart) and the infant was given a relatively uninteresting toy (e.g. plain soft toy) with which to play. Parents were sat behind their infant, not touching them and not interacting with them. When the infant was looking down at the toy, El called him/her by name, waited for eye contact, and then, with an excited facial expression and gasp, turned to look at one of the faces for a few seconds. El alternated her gaze between the infant's eyes and the target several times, maintaining the excited expression and completely turning her head each time. After a few seconds this procedure was repeated for the face on the other side of E1.

Pointing training condition

Following the gaze test, the dyads in the pointing training condition took part in a series of activities designed to illustrate to the parent how they might demonstrate pointing to their infant in the home while maintaining the infant's attention. First, the parent came to sit with their child on their knee, 1 m from a table with a box on top. E2 sat next to them as they watched a puppet show that E1 performed from behind the box for 3 minutes. E2

[4] Due to a change in employment of the first author, the data were collected in two parts at two university laboratories. The data for all the 9- and 11-month-olds and for nine of the 10-month-olds were collected in the first laboratory. Following the move, the data for 57 10-month-olds were collected in the second laboratory. Testing location and experimental condition were not confounded.

Table 1 *Number of males and females and mean age in days (with standard deviations) at each visit for each condition and age band*

	Pointing condition					Music condition				
Age in months	Male	Female	Mean age visit 1	Mean age visit 2	Mean age visit 3	Male	Female	Mean age visit 1	Mean age visit 2	Mean age visit 3
9	5	3	272 (3.20)	286 (3.37)	300 (3.67)	5	2	270 (4.67)	287 (3.37)	301 (2.48)
10	15	17	303 (3.03)	317 (3.57)	333 (3.58)	20	14	304 (2.65)	319 (3.37)	335 (3.35)
11	7	4	330 (4.02)	345 (3.52)	362 (4.49)	6	4	330 (3.72)	347 (5.28)	362 (2.73)
Total	27	24				31	20			

commented on the show enthusiastically, looking back and forth between the puppets and the infant, and pointed at the puppets. The parent was instructed just to watch.

Following the puppet show, infants remained at the table and read two picture books with E1 and the parent for 3 minutes. E1 pointed at interesting pictures both following in on what the infant was attending to and redirecting attention across the page. Parents were given the books at the end of the first session and asked to repeat this procedure each day for the duration of the study.

Again at the table, E1 next produced a hand-held bubble machine that sent bubbles into the air. For 3 minutes she pointed out bubbles and commented on them as they fell to the table. Parents were given a bubble machine at the end of the first session and asked to repeat this procedure each day for the duration of the study and/or walk around their house with their baby on the hip, pointing out and commenting on interesting things.

Still at the table, E1 next placed a row of cloth-covered pigeonholes and played a game of hiding and revealing toys in them. E1 hid a toy and then pointed to each pigeonhole asking, 'Is it going to be in here?', before revealing whether or not a toy was hidden inside. This procedure was used in the lab to demonstrate the kinds of contexts in which a parent might point for an infant, and this precise activity was not required to be repeated at home.

At the end of the training games for the pointing condition, E1 reiterated what the parents were required to do at home each day. Parents were asked to do book reading, bubbles and/or some 'distal pointing on the hip' at home for a total of 15 minutes a day. E1 explained that this might not always be possible and gave each parent a diary/checklist where they could keep a note of their progress and mark down anything interesting that they observed.

Music training condition

Following the gaze test, the dyads in the music condition watched the same puppet show as in the pointing condition except that E2 did not point at the puppets. Next, infants remained at the table and listened to nursery rhymes with E1 and the parent for 6 minutes. E1 played rhymes on a CD player, sang along and encouraged the infant to dance and do actions that went with the song. E1 produced some toy instruments (a drum and some maracas) that she and the infant played to the music. Parents were given the instruments and the nursery rhyme CD at the end of the first session and asked to repeat this procedure each day for the duration of the study.

Still at the table, E1 produced a bead slider toy that consisted of a wooden base attached to which were several wires with beads on. E1 span the beads and moved them from one end of the wire to the other with the infant for 3 minutes. This procedure was used to keep the length and variety of the first test session equivalent for both conditions.

At the end of the training games for the music condition, E1 reiterated what the parents were required to do at home each day. Parents were asked to sing nursery rhymes and/or play with the musical instruments for a total of 15 minutes a day. E1 explained that this might not always be possible and gave each parent a diary/checklist where they could keep a note of their progress and mark down anything interesting that they observed.

Test of declarative pointing

At the end of the first visit, children in both conditions were given an identical test of their communicative behavior. The layout of the room for this is illustrated in Figure 1 (based on the paradigm developed by Liszkowski and colleagues; Liszkowski, Carpenter, Henning, Striano & Tomasello, 2004). The test began

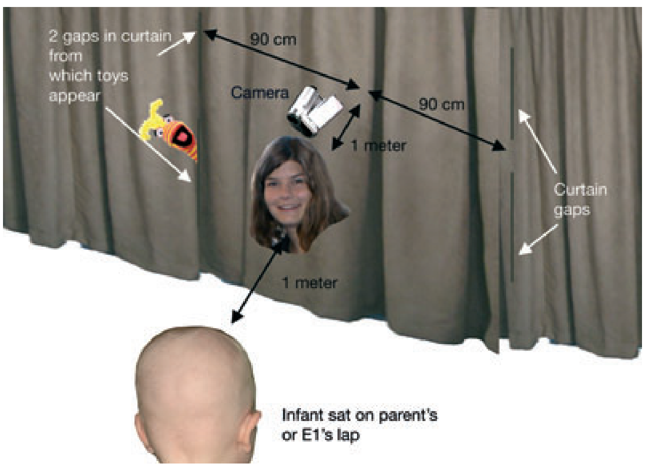

Figure 1 *Room layout for test of declarative pointing.*

with the infant sitting on their parent's knee (with their hands free) with E1 facing them. Behind E1 was a large (floor to ceiling, wall to wall) curtain from which toys were made to appear from one of four holes by E2. For each of 10 trials, a new toy appeared for 15 seconds. For every other trial, E1 looked only at the infant for the first 10 seconds, after which time E2 would call 'ten!' and E1 would look round to the puppets for the final 5 seconds. For the other half of the trials, E1 looked between the toys and the infant for the full 15 seconds (these trials helped to maintain infant interest). E1 always emoted positively if the infant gestured, vocalized or gaze checked her. E1 only ever talked about the emerging toys and never pointed at them. Parents were instructed to sit as still as possible.

After the first 10 trials, E1 and the parent swapped positions such that the infant sat on E1′s knee and faced their parent who had the curtain behind him/her. For a final five trials, the parent was instructed to look only at their child for the first 10 seconds (talking to them normally), after which time E2 would call 'ten!' and they could turn around to look at the puppets. This was done in case the infant was more inclined to interact communicatively with their parent than with an experimenter and to keep the infant engaged for longer.

For each child, the same 15 toys appeared in the same order from the same holes (randomly selected at the beginning of the experiment, equal number of toys presented to the left and right). This order was different for visits 1, 2 and 3 (but every child saw the same toys in the same order at each visit). If at any point an infant became distressed, that trial was skipped and, if necessary, the test brought to a conclusion. This was rarely necessary and all infants completed the majority of trials.

The test was video recorded with a digital camera that was filming through an opening in the curtain, immediately above the adult's head, facing the infant directly. Piloting had revealed that this camera angle was optimal for coding.

Visit 2

The main purpose of visit 2 was to keep parents involved in the study. It took place two weeks after visit 1 and followed the same procedure as visit 1 except that it began with 5 minutes of free play where the parent and child were videoed alone. This allowed us to measure how often parents pointed in free interaction with their children. For these 5 minutes, the infant was sitting on a play mat and the parent was instructed that they would be left to play for a few minutes while the experimenters set up. Parents were told that the video camera was running during this time and were asked if this was ok. Only 89 mothers were included in this analysis. The remaining 13 parent–infant dyads were excluded either because the mother's hands were not visible on the video (since we did not instruct the parents to remain in any particular position during free play) or because two caregivers were present during the session.

Visit 3

Visit 3 took place as near as possible to the first day of the child turning either 10, 11 or 12 months old. The procedure was identical for infants in both conditions and included a wide variety of contexts that piloting had shown stimulated communicative behavior. It began with a free play session (where E1, E2, the parent and the child were present) and test of gaze following. Next followed a puppet show as in visits 1 and 2 except that in both conditions E2 did not point at any time. After the puppet show, infants took part in the test of declarative pointing. This was identical to visits 1 and 2 except that five new toys were added, increasing the number of trials to 20. Next, the infant returned to sitting on their parent's knee and E1 explained the remainder of the procedure (which was designed to keep the infant entertained and to allow further opportunities for pointing). For a further 10 minutes E1 and the parent commented on objects in the room and the infant was free to look around.

Each visit lasted approximately 1 hour. A week after the first visit, E2 phoned parents to ask how they were getting on and to check whether they had any queries. At the end of the final session parents were debriefed about the study, told which condition they had been in and reminded that there was no evidence that the activities they practiced would benefit infants and there was no need to carry on with the daily activities.

Coding

For the test of gaze following, E2 coded live whether the infant (a) followed E1's gaze and looked directly at the target (=2 points), (b) looked only in the right direction of the target but not right at it (=1 point), or c) did not gaze follow at all (=0 points). Live coding was checked from the video recording. Thus for each visit a child could score a maximum of 4 points (scoring 2 for both the left and right test).

The videos of the infants' pointing behavior during all activities on visit 3 and the tests of declarative pointing on visit 1 were coded for the following characteristics:

1. Hand: The infant produced the point with the *left hand*, *right hand* or (rarely) *both hands*.
2. Finger: The infant produced the pointing gesture with their *index finger* (such that it was saliently separate from the other fingers, which were partially or entirely curled back) or with an *open hand*. Rare instances of pointing with a middle finger were counted as index finger points. Open hand gestures were coded only if only one arm was extended and the child was not leaning forward or otherwise apparently

attempting to reach for the referent (Franco & Butterworth, 1996).

3. Gaze checking: The infant *gaze checked* the interlocutor within 1 second of starting or ending the pointing gesture. For coding purposes, a point was considered to begin 1 second before the first video frame of maximal arm extension for that point. It was considered to end 1 second after the beginning of the arm retraction. Gaze checks were not counted if they were apparently produced suddenly in response to a sound (e.g. if the infant was pointing and looking at the target, whereupon the mother made a sudden and loud comment and the infant looked at her in response).
4. Voice: The infant *vocalized* within 1 second of starting or ending the pointing gesture. Vocalizations did not include laughing, crying or fussing.

Points to any target except to the interlocutor were coded (this latter case cannot be considered triadic communication but did happen occasionally; see Franco & Butterworth, 1996). For visit 1, only pointing gestures during the test of declarative pointing are measured (since this test was the same for both conditions). The full duration of visit 3 was identical for both experimental conditions and so data from all subtests were included. Therefore, any differences in pointing status and particularly pointing frequency from visit 1 to visit 3 will be partly due to this increase in sampling rate.

On the basis of the above categories, infants were categorized, for visit 1 and visit 3, according to whether or not they had pointed at least once in the following ways: pointed with an *index finger*, pointed with an *open hand* and pointed while *gaze checking* the interlocutor (regardless of hand posture). These categories are not mutually exclusive. Twenty percent of the data was coded by a second research assistant and Cohen's Kappas for pointing status (whether the child pointed at least once on a given visit or not) were as follows: Pointing status K = .87; index finger pointing status K = .76; open hand pointing status K = .78; gaze checking pointing status K = .80. To check reliability for between coders for the frequency of points produced, correlations were run and a high level of agreement was found (pointing frequency $r = .99$; index finger pointing frequency $r = .98$; open hand pointing frequency $r = .99$; gaze checking pointing frequency $r = .93$).

Finally, we coded the 5-minute free play session on visit 2 for how often the caregiver index finger pointed, which we refer to as *maternal pointing frequency*. Twenty percent of the data was coded by a second research assistant and there was very good agreement for the frequency of maternal points ($r = .99$).

Results

The parents' study diaries indicated that all the dyads had engaged in the 15-minute activities on the vast majority of days during the study. Infants found the testing sessions engaging and generally participated in all the component activities. In the following analyses, we consider both whether infants were observed to point by visit 3 or not (pointing onset) and how frequently they pointed on visit 3. We consider three types of pointing: *index finger*, *open hand* and *gaze checking* pointing. We tested whether the onset and frequency of these three types of pointing were predicted by:

1. Experimental condition (pointing training or music control)
2. Frequency of maternal pointing (as measured in free play on visit 2)
3. Infant gaze following abilities

For each of the point types, gender was not a significant predictor of pointing status nor pointing frequency on either visit 1 or visit 3. Thus, gender is not included as a variable in the analyses below. Due to the small number of 9- and 11-month-olds, data are presented collapsing across age (but the results hold when analyses exclude all 9- and 11-month-olds and only include the 10-month-olds for whom we have the most data). Where regression models are reported, age is included as a factor. When all other analyses were conducted separately for each age group, no further results of interest emerged.

The onset of pointing

Figure 2 presents the percentage of infants who were observed to point in various ways on visit 1 and visit 3.

To test whether children in the experimental condition were more likely to have begun pointing by visit 3 than children in the control condition, we fit logistic regression models to the data for visit 3 with pointing status (1 = observed to point, 0 = not observed to point) as the outcome variable and condition (1 = experimental, 0 = control) and age in months as the predictor variables. We summarize the results in the text and give full details of each model (including a pseudo R^2 for each

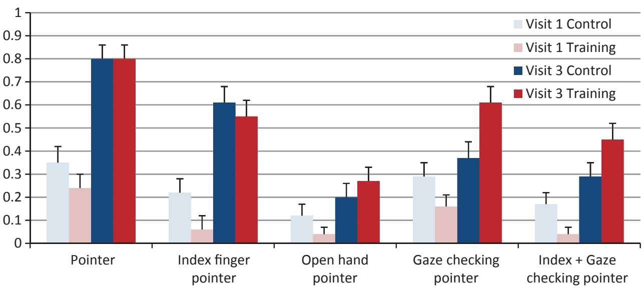

Figure 2 *Percentage of infants observed to be able to point as a function of experimental condition, visit and point type. (The category 'pointer' collapses across hand posture and reports the total number of infants observed to point either with an open hand or index finger. Error bars represent Standard Error of Mean.)*

model) in the Appendix. Since we are only interested in whether training had an effect on infants who were not already pointing on visit 1, for each of these analyses we restricted the dataset to those infants who were not observed to point in the relevant way on visit 1. For index finger pointing (N = 88), there was no significant effect of training but there was an effect of age (B = 1.167, SE = 0.438, z = 2.667, p = .008, exp(B) = 3.21). For open hand pointing (N = 91), there was no significant effect of either factor. For gaze checking pointing (N = 79), there was an effect of training (B = 1.141, SE = 0.479, z = 2.381, p = .01, exp(B) = 3.13) but no significant effect of age. Thus training appears to have had an impact on pointing in perfecting its use with gaze checking rather than by promoting the production of a specific hand posture.

There are large individual differences in the rate at which parents point in naturalistic settings. It is therefore possible that baseline differences in parent pointing might have swamped our artificial manipulation of parent pointing rate. To investigate this, we measured how often parents pointed in a free play situation on visit 2 (i.e. after random assignment to condition but outside of the pointing activities parents were required to engage in on a daily basis). Parents in the experimental condition did not point more frequently during free play (Mdn = 4) than parents in the control condition (Mdn = 3, W_s = 1037.5, *ns*). This suggests that parents in the training condition did not extend their pointing practice from the 15-minute daily activities to other settings. Logistic regression models were fit to all infants' data for whom maternal point frequency had been measured (N = 89) with maternal point frequency and age as predictors. Infants' index finger pointing status on visit 3 was not affected by maternal pointing but was affected by age (B = 1.155, SE = 0.407, z = 2.839, p = .005, exp(B) = 3.17). In contrast, open hand pointing status was affected by maternal pointing frequency (B = 0.133, SE = 0.051, z = 2.603, p = .009, exp(B) = 1.14) but was not affected by age. Likewise, gaze checking pointing status on visit 3 was affected by maternal pointing (B = 0.169, SE = 0.058, z = 2.902, p = .004, exp(B) = 1.18) but not by age. Thus, maternal pointing is associated with gesturing and gaze checking but does not appear to be effective in modeling the canonical hand posture.

To test the claim that the onset of index finger pointing depends heavily on the ability to follow gaze, we measured infants' ability to follow an experimenter's gaze to targets on the infant's left and right side at the beginning of each visit. Infants could score a maximum of 4 on each visit. These scores did not differ as a function of experimental condition but did increase over time (mean score for visit 1 = 1.98; mean score for visit 3 = 2.86). For each point type, logistic regression models were fit to the data for all 102 infants with age and gaze following score on visit 1 as predictors. For index finger pointing status at visit 3, both gaze following score (B = 0.347, SE = 0.140, z = 2.483, p = .013, exp(B) = 1.41) and age (B = 1.037, SE = 0.397, z = 2.614, p = .009, exp(B) = 2.82) were significant predictors. When we used the total gaze following score from all three visits, this relationship between gaze following and index finger pointing also held (total gaze following score: B = 0.260, SE = 0.070, z = 3.702, p = .0002, exp(B) = 1.30. Age: B = 1.040, SE = 0.413, z = 2.518, p = .012, exp(B) = 2.83). In contrast, neither age nor either measure of gaze following ability was a predictor of open hand pointing. Finally, the gaze following score for visit 1 was not a significant predictor of gaze checking pointing status but the total gaze following measure was (total gaze following score: B = 0.172, SE = 0.063, z = 2.752, p = .006, exp(B) = 1.19. NB: No effect of age).

Pointing frequency

In addition to looking at whether an infant can point in a given way, it is interesting to consider how often they choose to do so. This is particularly so given that pointing frequency in infancy has been shown to be a good predictor of later vocabulary (Colonnesi *et al.*, 2010). Figures 3 and 4 presents box plots of the frequency with which infants produced the different types of pointing gesture for each experimental condition on visits 1 and 3, respectively.

As can be seen from Figures 3 and 4, the frequency data were not normally distributed and so non-parametric tests were used to analyze them. If anything, the control condition pointed more frequently on visit 1 (see Figure 3). Thus, any significant advantage for the train-

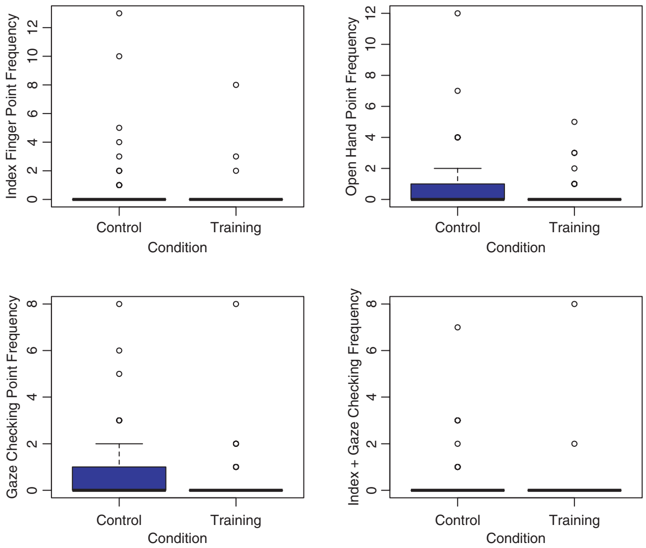

Figure 3 *Box plot for each point type showing pointing frequency on visit 1 as a function of experimental condition. (The boxes show the interquartile range, the whiskers extend to 1.5 times the interquartile range and the thick horizontal line in the box represents the median).*

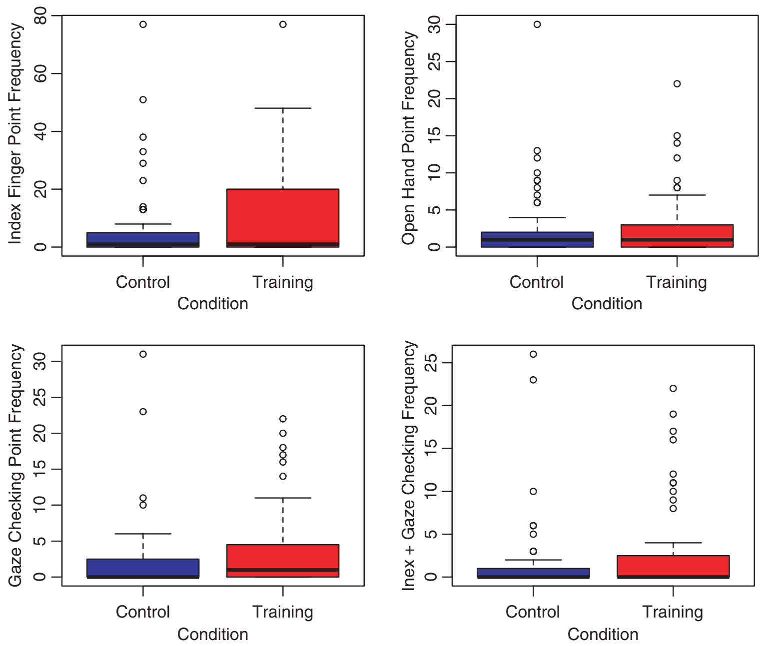

Figure 4 *Box plot for each point type showing pointing frequency on visit 3 as a function of experimental condition.*

ing condition on visit 3 is not due to differences that already existed prior to training. Below, for each type of pointing, we first report whether there were any significant differences between conditions at visit 1 before considering differences at visit 3. Wilcoxon rank sum tests showed the number of index finger points infants produced on visit 1 was significantly higher for the control condition ($W_s = 1100.5$, $p = .026$), whereas there was no significant difference between the conditions by visit 3. There was no significant difference between conditions in the rate of open hand pointing at either time point. The number of gaze checking points produced did not differ significantly at visit 1 but at visit 3 it was significantly higher in the training condition than in the control condition ($W_s = 1578$, $p = .023$, one-tailed) and this finding held when only index finger gaze checking points were considered ($W_s = 1524$, $p = .042$, one-tailed). This reinforces the suggestion that training is effective in socializing the gaze checking component of early pointing.

The frequency of maternal points in the free play session correlated significantly with the frequency of infants' index finger points ($r_s = .205$, $p = .05$), open hand points ($r_s = .385$, $p = .0001$) and gaze checking points ($r_s = .331$, $p = .002$) on visit 3.

Infants' scores on the test of gaze following on visit 1 were significantly correlated with the frequency of their index finger points on visit 3 ($r_s = .219$, $p = .027$). They were not correlated with the frequency of their open hand points but there was a borderline correlation with the frequency of their gaze checking points on visit 3 ($r_s = .192$, $p = .053$). Infants' scores on tests of gaze for all three visits combined were significantly or borderline correlated with the frequency of all point types (Index $r_s = .345$, $p = .0004$; Open $r_s = .193$, $p = .052$; Gaze checking $r_s = .283$, $p = .004$). Again, the relationship between gaze following and pointing is strongest for index finger points.

Discussion

To summarize, infant's *ability* to point declaratively with an index finger was predicted by infants' gaze following scores and by age but not by training condition or by maternal pointing frequency. In contrast, the *frequency* of index finger pointing on visit 3 was predicted by maternal pointing frequency and gaze following scores. Open hand declarative pointing ability and frequency were both predicted by maternal pointing frequency alone. Infants' ability to point while gaze checking was affected by training and the frequency of such points was affected by training, maternal pointing frequency and gaze following scores.

Of course, it is possible that our intervention, with 15 minutes of enhanced pointing experience per day, was too weak to influence the development of declarative index finger pointing. Infants in both conditions will have been exposed to at least some pointing and, as noted above, the differences in exposure due to training may have been swamped by the large individual differences in parent pointing. However, to the extent that we were able to estimate these individual differences in maternal pointing (from coding 15 minutes of free play), they were not associated with differences in the onset of index finger pointing either. Cross-cultural studies to date also suggest very similar age of pointing onset across cultures (Callaghan, Moll, Rakoczy, Behne, Liszkowski & Tomasello, 2011).[5] Thus, while these null results cannot rule out imitation or socialization as a mechanism for instigating the onset of index finger pointing, the frequency with which infants observe this gesture produced by their caregiver does not seem likely to be a strong determinant of index finger pointing onset. Rather, prior ability in gaze following seems to be key. Perhaps this prior ability is itself affected by socialization. This study was not designed to test this possibility but rather the direct socialization of pointing through parents' response to this gesture and/or infants' imitation of caregivers' gestures.[6] We found little evidence of such direct socialization.

These findings provide support for Spontaneous Onset accounts (with regard to predictions for index finger pointing) and Socialization accounts (with regard to predictions for gaze checking and pointing frequency). In line with Butterworth's (2003) proposal that indexical pointing is not socially transmitted, increasing parents' rate and sensitivity to pointing did not cause infants to point earlier. In contrast, infants' understanding of others' attention, as measured by gaze following, was a good predictor of pointing onset. This fits with observations of older infants, whose declarative pointing at 12 months has been related to understanding others' intentions, as measured in tests of advanced point following and imitating incomplete actions (Behne, Liszkowski, Carpenter & Tomasello, in press; Camaioni *et al.*, 2004; Liszkowski & Tomasello, 2011). However, it contrasts with studies finding a lack of inter-correlation for the different skills of joint attention (see Carpendale & Lewis, 2010, for a recent review).

In line with Socialization accounts, training was effective in increasing gaze checking while pointing. This is most compatible with theories whereby pointing gains communicative value in interaction with others (Carpendale & Carpendale, 2010). Likewise, maternal pointing frequency was related to the frequency of all three types of infant pointing. Such effects on early pointing frequency are important given that the rate at which infants point is a particularly strong predictor of later language skills (Colonnesi *et al.*, 2010; Masur, 1983; Rowe & Goldin-Meadow, 2009).

How might the effect of training on gaze checking pointing have played out? Parents were specifically asked to increase the rate at which they pointed for 15 minutes each day. However, it is likely that our training caused parents to change a number of things. We anticipated that parents would become more responsive to their infants' points, for example. Additionally, as one reviewer suggested, there may have been more exchange of gaze as parents attempted to direct their infants' attention. We attempted to limit such differences between conditions by having a control condition that was also socially engaging (see Gerry *et al.*, 2012, for recent evidence that active music practice achieves this). However, there were possibly aspects of triadic communication that were promoted that went beyond caregivers' production of and response to gesture. This could be tested with more sophisticated methods, perhaps using head-mounted eye-tracking (Franchak, Kretch, Soska & Adolph, 2012).

With evidence for both spontaneous onset and socialization accounts, it is interesting to consider whether we found any evidence of pointing initially only having a contemplative function. On the one hand, the fact that the gaze checking component of pointing is affected by training and maternal pointing suggests that it might be a later development. This might lead us to speculate that infants do not initially understand the effect their gestures have on their caregiver's attention (much like the way infants can follow a pointing gesture but not succeed on Behne, Carpenter and Tomasello's (2005) test of point comprehension). On the other hand, we have evidence of very early gaze checking in a large number of infants in this study, even when considering only those in the control condition.[7] Of course, gaze checking is not the only possible indicator of joint attention and it can be performed for social referencing rather than communicative purposes (Akhtar & Gernsbacher, 2008; Bates, 1976; Leroy *et al.*, 2009; Leung & Rheingold, 1981; Masur, 1983). Thus, it is difficult to establish whether the initial instances of pointing are communicative. Diary studies such as that of Carpendale and Carpendale (2010) indicate that infants do point in isolation early on and it seems unlikely that they are doing so with communicative intent but, since we have no

[5] Note, however, that recent findings indicate that dramatic differences in the amount of time infants spend in joint attention with their parents may affect pointing onset (Liszkowski, 2011). Future studies of this type might investigate whether differences in frequency of triadic interaction impact upon the onset of pointing directly or whether they affect precursor developments, such as gaze following, that are necessary for pointing to emerge. Perhaps more importantly, future studies might establish whether infants benefit from different learning mechanisms according to the relative timing of different social cognitive advances and environmental inputs. For example, it is possible that early pointers depend more on socialization and later pointers more on imitation.

[6] In relation to the role of imitation in gesture development, the strong predictive relationship between maternal pointing frequency and the infants' declarative open hand pointing onset and frequency is worthy of further investigation. This might suggest that the arm extension component of distal declarative pointing is learnt in part by imitation. On such an account, imitation of arm extension would combine with socialization of gaze checking whereas the index finger component of pointing would come online as prerequisite social-cognitive developments are in place. As Lock *et al.* (1990) noted, however, a full explanation of the origins of pointing is unlikely to be as simple as this.

[7] Occasionally, it even appeared that infants were actively struggling to co-ordinate gaze checking an interlocutor with pointing at an object such that the infant would look at the object with interest then switch gaze to the interlocutor and point to them (see also Franco & Butterworth, 1996). This might be taken as evidence that infants are attempting to monitor and manipulate their interlocutor's attention very early on. We also found that the pointing gestures of these infants were far more likely to be right handed than left, perhaps also suggesting early integration with left-lateralized communicative networks.

necessary and sufficient markers by which to judge whether a gesture was produced with communicative intent, it is difficult to be certain. Clearly, we need a better account of what early communicative intentions amount to and how they are evidenced in this 9–12-month period. A satisfying solution to this problem awaits methodological innovation.

To conclude, we have found evidence that the ability to point specifically with the index finger develops in synchrony with the ability to follow gaze. Socialization, as manipulated experimentally, plays a role in determining the onset and frequency of gaze-checking-while-pointing. Imitation may also play a role once pointing has begun since maternal pointing frequency is associated with the frequency of all the infant gestures studied (although this relation could be explained in a number of ways including the infant influencing the parent). This pattern of results is compatible with an account whereby infants point with their index finger spontaneously as soon as prerequisite social-cognitive developments are in place whereupon the gesture is rapidly socialized such that infants come to point more frequently and check their interlocutor's attention more accurately while communicating.

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Appendix: Logistic regression model details

Tests of the effect of condition on onset of index finger, open hand and gaze checking points

NB: To test the effect of condition on training, models are fitted to data from infants who did not already point in the given way on visit 1.

Table A1 *Logistic regression model fitted to data for index finger pointing (*N *= 88. This breaks downs as follows:* $N_{9months\_control} = 6$; $N_{9months\_training} = 8$; $N_{10monthscontrol} = 29$; $N_{10months\_training} = 30$; $N_{11months\_control} = 5$; $N_{11months\_control} = 10$*)*

	B	*SE*	*z* (Wald)	*p*	*Exp b*
(Intercept)	−11.314	4.362	−2.594	.009	
Condition	−0.311	0.453	−0.687	.492	0.73
Age	1.167	0.438	2.667	.008	3.21

Model LR $\chi 2 = 8.59$, df = 2, $p = .0136$. C = 0.64, Dxy = 0.28. Nagelkerke $R^2 = 0.124$.

Table A2 *Logistic regression model fitted to data for open hand pointing (N = 91. This breaks downs as follows:* $N_{9months\_control} = 7$; $N_{9months\_training} = 8$; $N_{10monthscontrol} = 31$; $N_{10months\_training} = 29$; $N_{11months\_control} = 6$; $N_{11months\_control} = 10$*)*

	B	*SE*	*z*	*p*	*Exp b*
(Intercept)	0.958	4.601	0.210	.835	
Condition	0.679	0.560	1.210	.226	1.97
Age	−0.282	0.462	−0.610	.542	0.75

Model LR $\chi2 = 1.82$, df = 2, $p = .402$. C = 0.601, Dxy = 0.20. Nagelkerke $R^2 = 0.032$.

Table A3 *Logistic regression model fitted to data for gaze checking pointing (N = 79. This breaks downs as follows:* $N_{9months\_control} = 6$; $N_{9months\_training} = 8$; $N_{10monthscontrol} = 26$; $N_{10months\_training} = 27$; $N_{11months\_control} = 4$; $N_{11months\_control} = 8$*)*

	B	*SE*	*z*	*p*	*Exp b*
(Intercept)	−5.234	4.193	−1.250	.212	
Condition	1.141	0.479	2.380	.017	3.13
Age	0.443	0.418	1.060	.290	1.56

Model LR $\chi2 = 7.26$, df = 2, $p = .0265$. C = 0.667, Dxy = 0.335. Nagelkerke $R^2 = 0.117$.

Tests of the effect of maternal pointing on onset of index finger, open hand and gaze checking points

NB: Models are fitted to the data from infants whose parents contributed a measure of maternal pointing ($N = 89$ in all cases. $N_{9\text{-months}} = 15$, $N_{10\text{-months}} = 54$, $N_{11\text{-months}} = 20$).

Table A4 *Logistic regression model fitted to data for index finger pointing*

	B	*SE*	*z*	*p*	*Exp b*
(Intercept)	−11.515	4.064	−2.830	.005	
Maternal points	0.039	0.049	0.810	.419	1.04
Age	1.155	0.407	2.840	.005	3.17

Model LR $\chi2 = 11.08$, df = 2, $p = .004$.C = 0.694, Dxy = 0.389. Nagelkerke $R^2 = 0.157$.

Table A5 *Logistic regression model fitted to data for open hand pointing*

	B	*SE*	*z*	*p*	*Exp b*
(Intercept)	−1.144	4.359	−0.260	.793	
Maternal points	0.133	0.051	2.600	.009	1.14
Age	−0.066	0.437	−0.150	.880	0.94

Model LR $\chi2 = 7.42$, df = 2, $p = .025$. C = 0.697, Dxy = 0.395. Nagelkerke $R^2 = 0.119$

Table A6 *Logistic regression model fitted to data for gaze checking pointing*

	B	*SE*	*z*	*p*	*Exp b*
(Intercept)	−6.297	3.805	−1.650	.098	
Maternal points	0.169	0.058	2.900	.004	1.18
Age	0.551	0.377	1.460	.144	1.73

Model LR $\chi2 = 14.29$, df = 2, $p < .001$.C = 0.0.731, Dxy = 0.463.Nagelkerke $R^2 = 0.198$.

Tests of the effect of infant gaze following ability on onset of index finger, open hand and gaze checking points

NB: Models are fitted to the data from all 102 infants. Gaze following ability on visit 1 (a score out of 4) is used as a predictor. Similar results hold when the total gaze following score (out of 12) from all three visits is used (as summarized in the main text) except that the total gaze following score was a better predictor of gaze checking pointing onset than was the visit 1 score, for which the corresponding model does not have a significant fit to the data (see below).

Table A7 *Logistic regression model fitted to data for index finger pointing*

	B	*SE*	*z*	*p*	*Exp b*
(Intercept)	−10.751	3.990	−2.690	.007	
Gaze following score	0.347	0.140	2.480	.013	1.41
Age	1.038	0.397	2.610	.009	2.82

Model LR $\chi2 = 15.22$, df = 2, $p < .001$.C = 0.714, Dxy = 0.429. Nagelkerke $R^2 = 0.186$.

Table A8 *Logistic regression model fitted to data for open hand pointing*

	B	*SE*	*z*	*p*	*Exp b*
(Intercept)	−2.193	4.045	−0.540	.588	
Gaze following score	0.121	0.073	1.670	.095	1.13
Age	0.008	0.403	0.020	.983	1.01

Model LR $\chi2 = 3.06$, df = 2, $p = .217$. C = 0.601, Dxy = 0.203. Nagelkerke $R^2 = 0.175$.

Table A9 *Logistic regression model fitted to data for gaze checking pointing*

	B	*SE*	*z*	*p*	*Exp b*
(Intercept)	−6.332	3.648	−1.740	0.083	
Gaze following score	0.172	0.063	2.750	0.006	1.19
Age	0.500	0.361	1.380	0.166	1.65

Model LR $\chi2 = 11.21$, df = 2, $p = .004$.C = 0.68, Dxy = 0.36. Nagelkerke $R^2 = 0.139$.