



## Twelve-month-olds' comprehension and production of pointing

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This study explored whether infants aged 12 months already recognize the communicative function of pointing gestures. Infants participated in a task requiring them to comprehend an adult's informative pointing gesture to the location of a hidden toy. They mostly succeeded in this task, which required them to infer that the adult was attempting to direct their attention to a location for a reason – because she wanted them to know that a toy was hidden there. Many of the infants also reversed roles and produced appropriate pointing gestures for the adult in this same game, and indeed there was a correlation such that comprehenders were for the most part producers. These findings indicate that by 12 months of age infants are beginning to show a bidirectional understanding of communicative pointing.

Young children begin to communicate with others using gestures long before they are able to express themselves linguistically. To explore the roots of children's communicative abilities, researchers have thus focused on their gestural communication, especially infant pointing (see e.g., Butterworth, 2003; Goldin-Meadow & Butcher, 2003; Tomasello, Carpenter, & Liskowski, 2007, and Volterra, Caselli, Capirci, & Pizzuto, 2005, for reviews). However, whereas there is a wealth of studies examining infants' production of these gestures, little is known about infants' comprehension of communicative pointing. A number of researchers have examined the early development of point comprehension (e.g., Butterworth & Grover, 1988, 1990; Butterworth & Itakura, 2000; Carpenter, Nagell, & Tomasello, 1998; Lempers, 1979; Leung & Rheingold, 1981; Morissette, Ricard, & Decarie, 1995; Murphy & Messer, 1977; see also Caron, Kiel, Dayton, & Butler, 2002; Deak, Flom, & Pick, 2000; Flom, Deák, Phill, & Pick, 2004), but they typically used simple point following as an index of comprehension; that is, they tested whether infants would turn and look in the indicated direction, and showed that

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by 12 months of age infants are able to locate an indicated target (see, e.g., Carpenter *et al.*, 1998, for a longitudinal study).

However, while point following clearly assesses infants' spatial or 'geometric' understanding of pointing (Butterworth & Grover, 1990), it is unclear to what extent it assesses their communicative understanding. The problem is that simply following the direction of gazing and pointing can be done without recognizing the other's communicative intent, that is, without comprehending that the gazer or pointer intends to direct one's attention to something and so to communicate. For example, many animal species, including all of the great ape species (e.g., Bräuer, Call, & Tomasello, 2005), reliably follow gaze direction, but this in itself is generally not considered evidence of their communicative understanding. This is because following another's gaze or point direction could also be an adaptive response performed automatically without recognizing that the other individual produced this gesture because he or she wanted the observer to attend to or do something.

To distinguish such simple gaze or point following from the comprehension of an intentional communicative act, what is needed is a task in which the addressee must follow the point and, in addition, make inferences about *why* the other person is directing her attention in this way. One task with this structure is a hiding-finding game that has been conducted with 1- and 2-year-old children (Behne, Carpenter, & Tomasello, 2005; Povinelli, Reaux, Bierschwale, Allain, & Simon, 1997; Tomasello, Call, & Gluckman, 1997). In this game, when an adult points to a box, the child not only needs to follow the direction of the pointing gesture, but in addition makes the inference that the pointer wants them to know that the sought-for toy is inside. That this inference is not as trivial as it appears to us becomes clear in similar studies with great apes. Even though apes may follow the point to the box, they usually do not make the inference that the pointer wants them to know that the hidden food is inside (see Call & Tomasello, 2005, and Miklósi & Soproni, 2006, for reviews). This is not because they cannot make inferences in general – they can in other situations involving both causal relations in the physical world (Call, 2004) and the behaviour of others in different contexts (Hare & Tomasello, 2004).

What young children are doing in this situation is understanding the gesturer's communicative intention. When someone points and gazes to a box, children's attention is drawn to it naturally – as is apes' – but then children go on to wonder why the person is directing their attention to this box: why is this box to which she is pointing relevant to our interaction? This question presupposes that the gesturer is being helpful (informative), and it also assumes some common ground between the gesturer and the searcher that supplies the answer (e.g., she thinks it is relevant for my search for the toy).<sup>1</sup> It is likely that great apes either do not wonder why the gesturer is pointing or else they do not assume a helpful motive (Tomasello, 2008; see also, e.g., Call, Hare, & Tomasello, 1998; Gómez, 2005; Hare & Tomasello, 2004).

To explore the roots of our understanding of communicative pointing gestures, infants' ability needs to be assessed using a task such as the hiding-finding game (see Pfister, 2010: 17). Since infants already begin pointing for others at around 12 months, one interesting question is whether, beyond simple point following, infants this age

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<sup>1</sup> Please see Breheny (2006), Csibra (2010), Pfister (2010), and Tomasello (2008) for more detailed descriptions and in-depth discussions of how best to characterize young children's communicative understanding and of how these more minimal accounts of children's understanding relate to linguistic theories of adult intentional communication, in particular Gricean communicative intentions and relevance theory.

already comprehend the communicative/informative function of pointing. So far, the youngest age at which infants have been tested in this regard is 14 and 18 months (Behne *et al.*, 2005; see also Aureli, Perucchini, & Genco, 2009). As a group, 14-month-old infants performed significantly above chance in the described hiding-finding game, that is, they tended to use the adult's pointing gesture to guide their search for the hidden toy. However, individually, none of the 14-month-olds performed significantly above chance on their own and their success rate on the pointing trials was significantly lower than that of 18-month-olds (see Gräfenhain, Behne, Carpenter, & Tomasello, 2009; Liebal, Behne, Carpenter, & Tomasello, 2009 for related findings).

This pattern of findings could be explained in two ways. The first is a 'conceptual' explanation, which proposes that while infants reliably follow points by the end of the first year, they only really begin to comprehend something about the communicative intent behind pointing gestures sometime during their second year. The second is a 'performance' explanation, which proposes that infants at the beginning of the second year already comprehend others' informative pointing gestures, but that they do not consistently show this, because specifics of the tasks present additional challenges and distractions. Take, for example, the containers used for hiding: Infants may think that the point is directed at the container itself as an object, not as a location – especially since containers are often intriguing objects to infants this age (perhaps even more so than the toys used as 'baits'). The need to get up and move to the hiding location may also present a challenge, as this can be a task in itself for infants this age for whom walking on their own is still quite a new skill. To distinguish between the two explanations, a version of the task is needed, which retains its basic structure but reduces the task demands involved.

A further question is how young infants' understanding of others' pointing gestures relates to their own pointing gestures. If there is a relation between the comprehension and production of informative pointing from something near the outset, then this would bolster the interpretation that infants do comprehend other's communicative intentions at this young age. Previous studies on the relation between infant point production and comprehension (e.g., Camaioni, Perucchini, Bellagamba, & Colonesi, 2004; Carpenter *et al.*, 1998; Desrochers, Morissette, & Ricard, 1995; Lempers, 1979; Leung & Rheingold, 1981; Woodward & Guajardo, 2002) are inconclusive with regard to this question, either because their analyses did not include correlations of infant point comprehension and production or because again simple point following was used as an index of comprehension<sup>2</sup>. To explore the relation between point production and comprehension with respect to infants' communicative understanding, we need to assess point comprehension in a task that examines infants' comprehension of the communicative intent behind pointing gestures. If infant point comprehension, as assessed by such a task, correlated with infants' own use of informative pointing gestures (see Liszkowski, Carpenter, Striano, & Tomasello, 2006; Liszkowski, Carpenter, & Tomasello, 2008), this would support the interpretation that infants' appropriate responses to others' pointing gestures reflect their underlying understanding of the communicative function of pointing. If such a correlation between comprehension and production of informative pointing is apparent at 12 months, it would provide evidence in favour of the claim that infants really know what they are doing from a communicative

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<sup>2</sup> Woodward and Guajardo (2002) used looking time measures rather than point following, but they too concluded that they 'did not explore infants' understanding of the communicative function of points' (p. 1082).

point of view - bidirectionally in both comprehension and production - in their early gestural communication.

In the current study we thus tested 12-month-old infants using the basic paradigm of Behne *et al.* (2005) to determine whether infants this young could comprehend an adult's informative pointing gestures. In order to prevent infants from being misled in their interpretation of the gesture or distracted by additional factors, we created a new version of the game, which allowed infants to remain stationary and to search for toys hidden beneath pieces of cloth. In addition, infants were also given the opportunity to reverse roles and point in this same way for a searching adult, to investigate whether infants' abilities in these two tasks would be correlated.

## Method

### Participants

Twenty-nine infants (16 girls, 13 boys) were included in the final sample. Their mean age was 12 months, 16 days (range = 12 months, 2 days - 12 months, 30 days). Infants were recruited in a medium-sized urban city in Germany from a database of parents who had been initially contacted via the city's birth register and had volunteered to participate in child development studies. Seven additional 12-month-olds (all boys) took part but were not included in the final sample because they did not participate in the warm-up phase of the hiding game (see below for details) or because they became too tired and fussy during the hiding game.

### Design

Infants first participated in the comprehension task - a hiding game in which the infants acted as searcher. They then participated in the production task, in which they witnessed the hiding of an object and then had the opportunity to inform a searching adult of its hiding location by pointing themselves. In designing the task we chose to present the two tasks in a fixed order rather than to counterbalance order across infants. This was based on considering the advantages and disadvantages of the two designs in relation to the specific questions of our study: (1) do 12-month-olds comprehend others' communicative pointing and (2) how is individual variation in comprehension related to variation in the tendency to point themselves. As all infants received the same treatment, and as there was no differential rewarding since infants always got the hidden toy regardless of their search performance, we can rule out that the order of presentation confounded patterns of individual variation. A fixed-order methodology is standard practice in research on individual differences (for more details see Carlson & Moses, 2001).

Whereas all 29 participants took part in the comprehension task, only 23 of them went on to take part in the production task - the other six had become too tired or fussy for the second game. There was no significant difference in performance on the comprehension task between those infants who went on to take part in the production task and those who did not (Mann-Whitney  $U = 48.0$ ,  $n_1 = 6$ ,  $n_2 = 23$ ,  $p = .289$ ).

### Materials

Two containers covered by identical pieces of cloth (each *ca.* 30 × 30 cm<sup>2</sup>) served as hiding locations. The containers were mounted on a posterboard (68 × 48 cm<sup>2</sup>), so



**Figure 1.** The apparatus and E's pointing gesture in the comprehension task. The child was seated at an equal distance to the two hiding locations, at the opposite side of the table (i.e., roughly 70 cm away from E).

that after the hiding the experimenter (E) could easily push the covered boxes towards the infants and within their reach. The two containers were flat boxes (base:  $12 \times 15 \text{ cm}^2$ ), which were only enclosed on three sides. The boxes were attached to the corners of the far side of the posterboard (i.e., 55 cm apart) with the open side facing inwards from E's perspective (see Figure 1). This meant that when the tops of the boxes were covered by the cloths, E could slide her hands into the boxes from the open side of the box. The height of each box was 7 cm at its open end, so that E1 could easily slide her hands in, and dropped to 2 cm at the end facing infants, so that they could easily see and remove the toy once they removed the cloth. Cloths rather than boxes with lids were used to conceal the hidden objects because piloting showed that opening a box was too interesting and distracting a task in itself for infants this age. The objects hidden were small toys (that could easily be hidden in one hand) in the comprehension task, and everyday adult objects in the production task (i.e., a bowl and a plastic lid on the warm-up trials and a key, a watch, a sock, and a packet of tissues on the four test trials). Two cameras were used to film the session from different perspectives.

### **Procedure**

After a play period to familiarize the infant with E and the assistant, the hiding game started. For this, infants sat on their parent's lap at the long side of a table (ca.  $130 \times 70 \text{ cm}^2$ ) facing E, and the assistant sat next to infants and their parent. Parents were instructed not to respond or interfere in any way.

### *Comprehension task*

The comprehension task consisted of a warm-up phase and a test phase. In the warm-up phase, designed to familiarize the infant with the set-up and materials of the game,

E 'hid' the toy in such a way that the infant could see where she placed it and she did not point to the toy's hiding location.

*Comprehension task: Warm-up.* To start, E held up a toy for the infant and, when the infant showed interest in it, she said, 'I'm going to hide this now' and placed it in one of the two cloth-covered boxes. That is, she took the toy in both hands cupped together, quickly lowered her hands underneath the table, transferred the toy into one hand, and then raised and presented her open hands, with the toy clearly visible in one of them. She then slid that hand underneath the cloth of the assigned box and pushed the posterboard towards the infant. If infants did not search for the toy, E encouraged them to do so by saying, for example, 'Where is it?' Two such visible hiding trials were conducted, with E placing the toy in each of the two hiding locations in turn (using her left hand to place the toy in the left box and her right hand for the box on her right). If the infant did not search at first or had problems finding the toy, the warm-up trials were repeated on both sides (for 13 infants the warm-up trials were repeated once and for three infants twice).<sup>3</sup>

*Comprehension task: Test phase.* Once the infant had searched successfully in both hiding locations, the test phase began. It consisted of eight trials in which E hid the toy non-visibly and then indicated the hiding location using a pointing gesture. On each trial E showed infants a new small toy and then hid it in one of the two locations. To do this, she took the toy in both hands, lowered her hands under the table, quickly transferred the toy into the fist of one hand (hidden), and then slid each hand (in a fist) under one of the two cloths of the hiding boxes, depositing the toy in one of them. She then pulled out her hands, adjusted the cloths if necessary (touching each box with one hand simultaneously, to avoid highlighting one of the boxes), and presented her empty hands. The assistant sitting with the infant checked that there were no visible or audible signs as to the toy's location during hiding.

After hiding it, E indicated the toy's location with a pointing gesture. That is, she called the infant's name, established eye contact, and then pointed and looked ostensively to the hiding location and pushed the posterboard towards the infant, while continuing to point and look at the location. If infants did not search or got distracted, E addressed them again and continued to point and look to the hiding location, occasionally shifting her gaze between the location and the infant. When pointing to the left-hand box, E used her right hand (and vice versa), holding it roughly at the midline of her body (in order to control for distance cues) with her extended index finger pointing towards the hiding location. She continued her gesture until the infant discovered the toy. If an infant did not search for the toy (within roughly 20 s) or if the infant did not find it, E removed the cloth and showed her the toy. Thus, regardless of whether or not infants were successful in their search, they always had the opportunity to retrieve and play with the toy. This was done to ensure that infants who were unsuccessful did not quickly lose interest in the game due to frustration. Left and right hiding locations were counterbalanced across the eight trials for each infant. For approximately half the infants, the hiding location in

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<sup>3</sup> There were no performance differences in the test phase of the comprehension tasks between those infants who required more warm-up trials ( $M = 76.4\%$  correct searches,  $SD = 17.6\%$ ) and those who did not ( $M = 70.6\%$  correct searches,  $SD = 23.0\%$ ) ( $t[26] = 0.76$ ,  $p = .452$ ).

the first test trial was on the same side as in the last warm-up trial and for the others it was on the other side. The predetermined sequence of hiding locations was random, except that toys were not hidden on the same side more than twice in a row. Different pairs of cloths that varied in colour and material were used on different trials (both during the warm-up and the test trials) to minimize perseveration errors.

*Production task*

The production task also consisted of a warm-up phase and a test phase. The general set-up was similar to that of the comprehension task, except that the infant, parent, and assistant switched positions with E, so that infants (seated on their parent's lap) were now at the side of the table where they could witness the objects being hidden and E was on the opposite side in the place of the searcher. In other words, the change in set-up mirrored the changed roles, with E now searching and the infant witnessing the hiding process, (and with the assistant again sitting next to the infant and their parent).

*Production task: Warm-up.* Two warm-up trials introduced this change of situation. First the assistant presented an object to E and the infant, and E expressed her interest in the object, saying for example, 'Oh, that's nice' and 'I want to have the [X]', while reaching for the object. The assistant then announced that she was going to hide the object. Ensuring that the infant was watching (saying 'Look') and with E also watching ostensibly, the assistant visibly put the object into one of the hiding locations and covered it with a cloth. (She also adjusted the other cloth, so that she had touched both locations). Two different cloths (i.e., different colour and type of material) were used to cover the two hiding locations in the production task, to make it easier for infants to remember where the object was hidden. After hiding, the assistant pushed the posterboard towards E, who uncovered the cloth on the correct side and expressed pleasure about finding the object she wanted. The same procedure was repeated for the second warm-up trial, in which the object was hidden in the other location.

*Production task: Test phase.* The subsequent test phase consisted of up to four trials. (Specifically, 19 of the 23 infants who participated completed all four trials. Two infants completed three trials and two completed just two trials, because they became too tired to continue.) The beginning of each trial was the same as before. That is, the assistant first showed an object to the infant and E by placing it visibly in the centre of the posterboard between the two hiding locations, E expressed her interest in the object and the assistant announced that she was going to hide it. However, in the test trials the assistant then asked E to turn around, E covered her eyes and swivelled around with her chair and bent over, lowering her head. The assistant then hid the object, ensuring that the infant watched this. When introducing the object, showing interest in it and hiding it, both the assistant and E repeatedly labelled the object so that the infant was familiar with its label. E then turned around and looked for the object. She first looked at the location where the object used to be, showed surprise, and addressed the infant by name with a questioning facial expression and questioning intonation, while holding her arms up with palms facing upwards. She then asked infants, 'Where is it? Where has it gone?', and then, 'The [X]? Where is the [X]?' If infants had not pointed yet, the assistant encouraged the infant, saying 'Do you know where the [X] is?' If the infant did

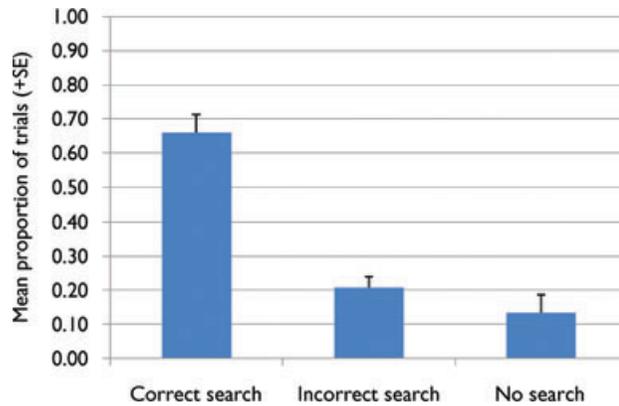
not respond within roughly 30 s (starting from when E began her search), the assistant uncovered the correct hiding location and E retrieved the object she had been looking for. E always responded with delight at having found the object (saying, e.g., 'Ah, there it is! That's what I was looking for. Great!'), regardless of whether the child had pointed or the assistant had uncovered it. On each subsequent trial the assistant used two new differently coloured cloths to cover the possible hiding locations.

### Data coding and analyses

Infants' responses in both tasks were coded from videotape. For the comprehension task, infants' responses on each of the eight test trials were scored as *correct search* if infants first searched in the indicated location, *incorrect search* if they first searched on the other side, or as *no search* if infants did not search at all. To assess inter-rater reliability a second coder scored the data of six randomly chosen infants (21%) independently. Perfect inter-rater reliability (Cohen's kappa = 1) was obtained.<sup>4</sup> In order to analyse infants' performance, the number of trials with *correct search*, *incorrect search*, or *no search* was calculated for each infant. The proportion of correct searches was also calculated for each infant, based on the total number of trials in which the infant had shown a search response (i.e., excluding trials with *no search*). In addition to infants' search success, we also examined their tendency to perseverate, to check whether this may explain the pattern of errors for those infants who did not perform successfully. Thus, we scored whether infants searched in the same location as in their previous search or in the opposite location. If infants had not searched on the trial before, the previous trial on which they had searched was taken as a reference point. For their first test trial, their search choice was compared to their search behaviour on their last warm-up trial.

For the production task, first we wanted to distinguish whether infants pointed out the hiding location to communicate it to E or whether instead they simply acted instrumentally in order to try to obtain the toy themselves. Thus three types of responses were distinguished: (1) *pointing* towards the hiding location; (2) *reaching* towards the hiding location in an attempt to retrieve the toy for the self (i.e., leaning forward with the hand outstretched while looking at the hiding location, and not looking at or addressing E); or (3) *no response* (or irrelevant responses) to E's search. For each pointing response, our main interest was in whether or not infants pointed informatively for E. Since other types of pointing were possible (i.e., infants could have pointed to request the hidden objects) the pointing gestures were classified as: (1) *requestive*, if the pointing was accompanied by whining or requestive hand-grasping movements, (2) *non-requestive*, if the pointing was clearly not accompanied by such signs of request, or (3) *'not codable'* if, for example, the pointing was very brief or ambiguous. We also coded whether infants pointed with an extended index finger or with their whole hand. To assess inter-rater reliability, the data of six infants (26%) were coded by a second person. Inter-rater reliability for infants' responses (with agreement on all codes) was very good (Cohen's Kappa = .80).

<sup>4</sup> We also performed an additional reliability check to ensure that 'blind' coding yielded the same scores. Thus a new coder scored infants' response with part of the monitor obscured, so that she did not know where the toy was hidden or where the experimenter pointed. Again six children were randomly chosen and their responses were scored as 'toy found in first location searched', 'toy not found at first location searched', or 'no search'. Hundred percent agreement with the equivalent original coding scores was obtained.



**Figure 2.** Infants' overall performance in the comprehension task.

The comprehension and production tasks were coded by different coders (both for the original coding and for the inter-rater reliability), ensuring that the person coding the production task was unaware of infants' performance in the comprehension task and vice versa. To examine the relation between infants' individual performance on the two tasks we established success criteria for each task. For the comprehension task, infants' performance was considered successful if they performed significantly above chance individually, as shown by searching in the correct location on at least seven of eight trials (as determined by a one-tailed binominal test at a significance level of  $p < .05$ ). For the production task, success was defined as pointing to the hiding location on at least one occasion.

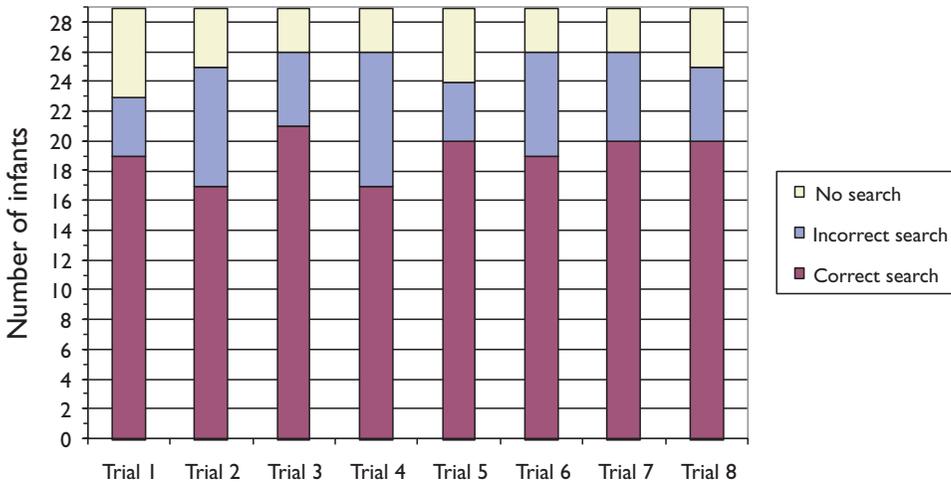
## Results

### Comprehension task

Infants searched in the location E pointed to significantly more often ( $M = 73.7\%$  correct searches,  $SD = 20.1\%$ ) than expected by chance (i.e., 50% correct searches) (one-sample  $t$ -test on the proportion of correct searches,  $t[27]^5 = 6.23$ ,  $p < .001$ ). Infants also showed significantly more correct responses (searching in the indicated location,  $M = 5.3$  trials,  $SD = 2.4$ ) than wrong responses (searching in the other location or not searching at all  $M = 2.7$  trials,  $SD = 2.4$ ) ( $t[28] = 2.89$ ,  $p = .007$ ), even though the inclusion of 'no search' among the wrong responses is a very conservative criterion. No gender differences were observed when looking at the proportion of correct searches (boys:  $M = 73.8\%$ ,  $SD = 17.3\%$ ; girls:  $M = 73.7\%$ ,  $SD = 22.9\%$ ;  $t[26] = 0.02$ ,  $p = .989$ ). Thus, as a group, infants used the adult's communicative gesture to guide their search for the hidden toy (see Figure 2).

Looking at their first-trial performance, the majority of infants already searched correctly on their very first trial (19 out of 29 infants; binominal test,  $p < .05$ ). No order effects were observed regarding the number of infants who searched correctly on each of the eight trials (Cochran's  $Q = 3.2$ ,  $n = 29$ ,  $df = 7$ ,  $p = 0.864$ ; see Figure 3 for

<sup>5</sup> The  $n$  for this analysis is 28 because one infant did not search on any of her eight trials. A further six infants only searched on two to seven of their eight trials, whereas the remaining 22 infants always searched for the hidden toy.



**Figure 3.** Infants' trial-by-trial performance in the comprehension task.

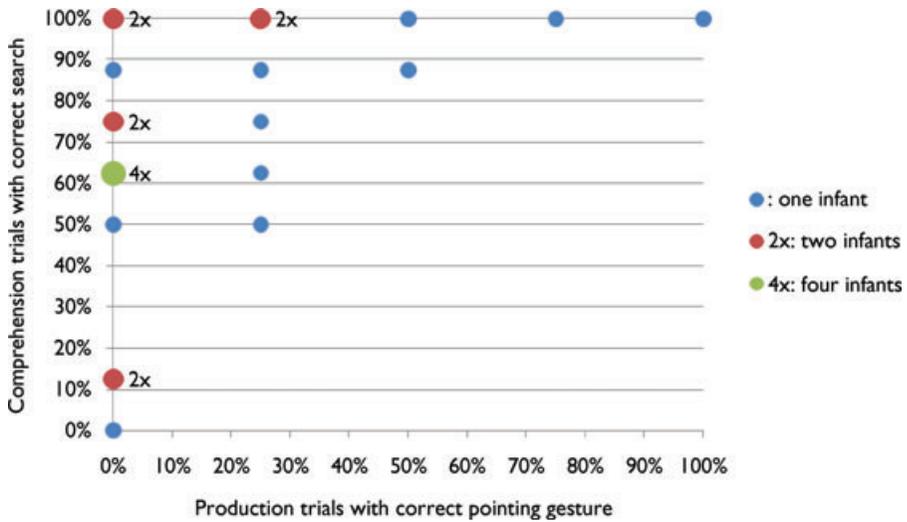
infants' performance on each trial).

To examine infants' individual performance, analyses focused on those 22 infants who had searched on all eight trials. Ten of these 22 infants searched correctly in seven ( $n = 3$ ) or all eight of their trials ( $n = 7$ ), thus performing above chance individually (binominal tests on individual performance, at least seven out of eight trials correct,  $p$ s < .05, one-tailed).

To examine infants' tendency to perseverate, a  $2 \times 2$  ANOVA was conducted on infants' search responses, with point comprehension (correct vs. incorrect search) and perseveration (same vs. opposite location) as within-subject factors. This analysis yielded a main effect of point comprehension ( $F[1, 28] = 38.18, p < .001$ , partial eta squared = .577), showing that infants searched significantly more in the location E pointed to than the other location. There was no main effect of perseveration ( $F[1, 28] = .58, p = .455$ , partial eta squared = .020), but a point comprehension X perseveration interaction ( $F[1, 28] = 22.97, p < .001$ , partial eta squared = .451). Follow-up tests showed that, when searching *incorrectly*, infants chose the *same* location as chosen previously, significantly more often than the *opposite* location (Paired  $t$ -test,  $t[28] = 4.11, p < .001$ ). No such pattern was observed for infants' correct searches (Paired  $t$ -test,  $t[28] = -1.10, p = .281$ ).

### Production task

Ten infants pointed to the correct hiding location for E on at least one trial, three infants only reached for the toy (on one or two of their trials), and the remaining ten infants showed neither response. Due to experimenter error for some infants ( $n = 12$ ) who had not pointed themselves on a given trial, the assistant ended that trial by pointing to the hiding location, instead of just uncovering it. To examine whether these infants were more likely to point themselves, as they might have mimicked the assistant's pointing on subsequent trials, we examined infants' pattern of responses in relation to the experimenter error: of those infants who witnessed the assistant point, four of 12 pointed and of those who did not, six of 11 pointed to the correct hiding location. (Points to the incorrect hiding location were very rare, they only occurred on 1.1% of



**Figure 4.** The relation between infants' performance in the comprehension and production task.

the trials). Thus, infants were no more likely to point to the hiding location themselves if the assistant had ended the previous trial(s) by pointing than if she had never done so (Fisher's exact test,  $n = 23$ ,  $p = .41$ ). For those six infants who pointed without ever having seen the assistant point, we examined their pointing behaviour in more detail. Infants tended to point before E explicitly stated what she was looking for (on 67% of trials with a correct point) and they always pointed before being prompted by the assistant. They pointed on 50.0% of their trials ( $SE = 12.9\%$ ), most frequently on their second trial (two pointed on trial 1, six on trial 2, one on trial 3, and two on trial 4). Their points were never accompanied by any signs of request and they typically pointed with their index finger (on 92% of all trials with a correct point).

### **Relations between the comprehension and production tasks**

The proportion of trials in which infants searched correctly in the comprehension task correlated with the proportion of trials in which they pointed for E in the production task (Spearman's rho<sup>6</sup> = .53,  $n = 23$ ,  $p = .01$ , see Figure 4).<sup>7</sup> In addition, this relation between comprehension and production was also observed when a criterion measure for infants' success in the two tasks was used: Infants who had performed above chance individually in the comprehension task (i.e., who had searched correctly on at least seven of eight trials) were more likely to be successful in the production task (i.e., to point at least once for E to the toy's hiding location) than those who had not (Phi = .47,  $n = 23$ ,  $p = .024$ ). We also reran the correlation analysis excluding those four infants who pointed after having

<sup>6</sup> Note that the same pattern of results is obtained if parametric rather than non-parametric analysis is used (Pearson correlation:  $r = .48$ ,  $n = 23$ ,  $p = .020$ ). This relation also holds if infant age is controlled for (Partial correlation controlling for age (in days),  $r = .47$ ,  $n = 23$ ,  $p = .027$ ).

<sup>7</sup> We also ran the correlation analysis excluding those trials in which infants did not search at all. Again, a significant correlation was found between the proportion of correct searches and the proportion of trials in which infants pointed for E (Spearman's rho = .49,  $n = 22$ ,  $p = .021$ ). (Again the Pearson's correlation yields the same pattern of results:  $r = .51$ ,  $p = .015$ .)

witnessed the assistant point on any of their previous trials, to ensure that the correlation we observed was not based on those infants mimicking the assistant's behaviour on subsequent trials. Importantly, the correlation was just as strong as the one observed for the whole sample (if anything, it was even a little stronger: Spearman's  $\rho = .60$ ,  $n = 19$ ,  $p = .007$ ).

Thus, a clear relation was observed between infants' comprehension of pointing gestures in the context of a hiding game and their own production of such gestures in the same situation.

## Discussion

The present study had two findings. The main finding was that infants aged 12 months were able to use the adult's pointing gesture to guide their search for the hidden toy. A second finding was that infants' individual variation in comprehending the communicative pointing gesture correlated with their own tendency to point to the hidden object for the searching adult, when given the opportunity to reverse roles. In our view, these findings suggest that, beyond simple point following, infants this age already begin to recognize the communicative function of the pointing gesture.

At first glance, infants' successful performance in the comprehension task appears to be inconsistent with previous studies showing that slightly older infants had some difficulties with similar tasks (see Behne *et al.*, 2005, Gräfenhain *et al.*, 2009). However, looking at the procedures in detail suggests that this discrepancy can be accounted for by differences regarding the task demands – in particular, infants' challenge to overcome their tendency to perseverate when searching repeatedly for a hidden object. Compared to previous procedures, we made a number of changes that reduced the level of distraction and delay involved in retrieving the hidden toy (i.e., infants did not need to walk or crawl to the hiding location, and they searched for toys hidden under cloths rather than in containers). Studies on the A-not-B error have demonstrated that these kinds of procedural factors affect infants' tendency to perseverate. For example, shortening the delay before infants retrieve the hidden toy decreases the likelihood of perseveration errors (see e.g., Diamond 1985; for a discussion of the possible causes of perseverative search behaviour see also Ruffman, Slade, Sandino, & Fletcher, 2005; Simmering, Schutte, & Spencer, 2008; Thelen Schöner, Scheier, & Smith, 2001; Topal, Gergely, Miklosi, Erdohegyi, & Csibra, 2008; among others).

Our finding regarding 12-month-olds' comprehension of pointing as a communicative gesture is in line with recent findings by Gliga and Csibra (2009) who demonstrated that infants this age appreciate the referential nature of deictic gestures and words (see also Csibra & Volein, 2008; Sodian & Thoermer, 2004; Yoon, Johnson, & Csibra, 2008). In their study, infants aged 13 months were presented with a scene of an actor who labelled and pointed to an object that was hidden behind a screen from the infants' view. Subsequently, infants were 'surprised' (i.e., they looked longer) when the named object was revealed to be not in the indicated location, but on the other side of the display. Our results support and extend this finding by showing that infants' recognition of pointing as a communicative/referential gesture not only guides their looking time patterns, but also their interactive responses in more real-life communicative exchanges. This is of particular interest as in many areas of cognitive development stark dissociations between looking time measures and related action responses have been observed (see e.g., Ahmed & Ruffmann, 1998; Berthier *et al.*, 2001; Hofstadter & Reznick, 1996; Hood, Carey, & Prasada, 2000; Hood, Cole-Davies, & Dias 2003).

Next we turn to the relation between infants' comprehension and production of communicative pointing, starting with a methodological consideration. In the fixed-order design we used, the comprehension task was always first and, as infants showed successful performance from their first trial on, it is clear that their performance did not depend on any experience acquired during the session. Regarding the production task, however, the picture is more complex. One possibility is that infants who pointed in the production task already arrived at the session with this competence. This is plausible in view of the finding that infants this age are motivated and able to point to the object that another person is searching for (Liszkowski *et al.*, 2006; Liszkowski *et al.*, 2008). The alternative possibility is that infants' pointing in the production task did, to some extent, depend on their experience of the comprehension task. That is, witnessing someone else point to the toy that they were searching for may have helped them later on to guide another person's search.

But the important point is that, even if infants did learn during the experiment, the ones who learned were mainly those who already comprehended pointing – as evidenced by the correlation between comprehension and production. This makes sense because the role-reversal imitation required for such learning presupposes an understanding of the intent behind the adult's communicative action (Tomasello, 1999; see also Carpenter, Tomasello, & Striano, 2005; Hobson & Lee, 1999). That is, although some kind of blind mimicking could conceivably have led to infants sticking out their fingers, it could not have led to the productions we observed, as children mostly pointed to the correct box, which changed on every trial.<sup>8</sup> To do what the adult did, correctly, they had to understand that in the comprehension phase the adult was pointing to help guide their search for the toy. Thus, infants who pointed in the production task either had the communicative competence required from the start or they had enough communicative understanding to recognize what it was the adult was doing in order to reproduce her communicative act when confronted with the reversed situation.

The facts that infants pointed correctly in the production phase and that their performances in the comprehension and production tasks correlated thus support the view that both tasks reflected infants' underlying communicative competence.<sup>9</sup> A related question concerns the relation between production and comprehension in the development of this communicative competence during the first year of life. Very little is known about the mechanisms and processes involved in the emergence of pointing, but different scenarios have been proposed (see Butterworth, 2003; Lock, Young, Service, & Chandler 1990; Woodward & Guarjardo, 2002). There is also an ongoing debate about whether point following and production could initially be learned separately (see

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<sup>8</sup> Furthermore, if infants' pointing were based on simple mimicking, one would expect the infants who had just witnessed the assistant's experimenter error in the production task (i.e., her pointing to the hiding location) to be more likely to point themselves. This, however, was not the case.

<sup>9</sup> The logic for this is as follows: Such a correlation is to be expected if infants' performance in both tasks reflects their underlying communicative ability, specifically their understanding of the communicative function of pointing. In contrast, such a correlation would be unexpected if infants had an isolated ability, restricted to one task (either point production or comprehension), and their performance in the other task was simply based on some alternative mechanism. Take the comprehension task: If, despite our efforts to control for this, infants' successful search performance were based, for instance, on a mechanism of local enhancement (i.e., that somehow the side pointed to was made more attractive to the infant), then one would not expect infants' search performance to correlate with their own use of pointing in the production task (especially once infant age was controlled for). Similarly, regarding the production task, if infants' pointing were just based on a simple heuristic (e.g., 'If I point there, the other person will give me the object I want') – without any deeper understanding of the communicative function of pointing, then one would not expect their performance in the production task to correlate with their point comprehension.

e.g., Triesch, Teuscher, Deák, & Carlson, 2006, for related learning models) or whether there is a close interrelation in development right from the start (see e.g., Woodward & Guarjardo, 2002). In the case of instrumental (rather than communicative) actions, such close interrelation between production and comprehension has been documented in a number of infant studies (e.g., Hauf, Aschersleben, & Prinz, 2007; Sommerville & Woodward 2005; Sommerville, Woodward, & Needham 2005).

Infants' success in both the comprehension and production task suggests that at least some 12-month-old infants already possess a bidirectional or agent-neutral understanding of communicative pointing – they seem to understand the function of the gesture from an agent-neutral point of view and are thus able to act appropriately both in the role of communicator and recipient. This contrasts with the egocentric understanding which may characterize infants' first use of gestures – as well as the (idiosyncratic) use of gestures by some non-human apes (e.g., Call & Tomasello, 2007; Goodall, 1986; Pika & Liebal, 2006; Tomasello 1999, 2008). For example, young infants may learn from their history of interaction that their caretaker will pick them up when they raise their hands over their head (and thus learn to produce this gesture as a request to be picked up; see Lock, 1978), but – the suggestion is – they would not understand such a hands-over-head gesture as a request addressed to them (ignoring for the moment the practical problems that such a request would entail). Some theorists have suggested a similar developmental story for the origin of pointing, proposing that it emerges from unsuccessful reaching movements (e.g., Vygotsky, 1966). Regardless of whether pointing emerges this way or not (see Butterworth, 2003, and Lock *et al.*, 1990, for critical discussions), our finding suggests that at least from 12 months on infants begin to show a more sophisticated bidirectional understanding of pointing.

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