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Communication about absent entities in great apes and human infants

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A B S T R A C T

There is currently debate about the extent to which non-linguistic beings such as human infants and great apes are capable of absent reference. In a series of experiments we investigated the flexibility and specificity of great apes' ($N = 36$) and 12 month-old infants' ($N = 40$) requests for absent entities. Subjects had the choice between requesting visible objects directly and using the former location of a depleted option to request more of these now-absent entities. Importantly, we systematically varied the quality of the present and absent options. We found that great apes as well as human infants flexibly adjusted their requests for absent entities to these contextual variations and only requested absent entities when the visible option was of lower quality than the absent option. These results suggest that the most basic cognitive capacities for absent reference do not depend on language and are shared by humans and their closest living relatives.

1. Introduction

The use of conventional symbolic systems allows humans to extend their communicative interactions beyond the here and now. Words, for example, denote things in the world and induce thoughts about these things even when the things themselves are perceptually absent to the speaker and the listener. They enable us to be precise about what it is that our interlocutor should envision and thereby allow us to make reference to specific absent entities.

Theories on the evolutionary origins of language listed reference to absent entities or displacement as one of the "design features" of human language (Hockett, 1960). To trace back the evolutionary history of this ability, the question is whether we can also find it in other animals or whether it is something specific to language and therefore uniquely human. The answer is yes, and no. On the one hand, animals like the western honeybee (*Apis mellifera*) manage to communicate to each other the precise location of a food source when the food source is perceptually absent. On the other hand, this form of communication lacks the flexibility and intentionality of human communication (Gould & Gould, 1988).

Human children start to show signs of comprehending the referential nature of words for absent entities at around 12 month of age. For example, they look and gesture more towards a display that matches the colour and location of a previously mentioned absent object suggesting that the word elicited a representation of that object (Saylor, 2004). Slightly older children also take into account a person's experience with an object when responding to an ambiguous referential request of an absent object (Saylor & Ganea, 2007). However, early comprehension of absent reference is rather fragile and influenced by the familiarity as well as the spatial location of the object that is referred to (Osina, Saylor, & Ganea, 2013; Saylor & Ganea, 2007). In terms of production, children only start to use words to refer to absent entities from around 18 month onwards (Veneziano & Sinclair, 1995).

Non-human great apes (hereafter apes) can use symbolic systems of communication to refer to absent referents after a process of enculturation and/or intensive training regime (Gardner, Gardner, & Van Cantfort, 1989; Lyn, Greenfield, Sayage-Rumbaugh, Gillespie-Lynch, & Hopkins, 2011; Savage-Rumbaugh, 1986). However, some authors have questioned whether symbol use in apes, especially the early studies, can be interpreted as evidence of absent reference (Savage-Rumbaugh, Rumbaugh, & Boysen, 1980; Terrace, 1985). For instance, Savage-Rumbaugh et al. (1980) argued that symbol use could merely reflect an association between producing the symbol and receiving its referent within a highly structured context. Nevertheless, even if language trained apes did use symbols to communicate about absent entities, this still does not answer the question of whether reference to absent entities is possible without symbols. The same is true for infants' production and comprehension of verbal reference to

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absent entities. To answer this question, one should study individuals who are non-linguistic but nevertheless exhibit signs for intentional communication such as non-enculturated apes and pre-linguistic human infants at around 12 months of age. Infants as well as apes in the laboratory use pointing gestures in an intentional and flexible way to request objects they desire (Leavens, Hopkins, & Thomas, 2004; Tomasello, Carpenter, & Liszkowski, 2007).

In theory, given enough shared experience or common ground, reference to absent entities should also be possible using pointing instead of a conventional symbolic system (Tomasello, 2008). For example, a child could point for her father to the empty cookie jar, thereby asking for more cookies, because both father and child have it in their common ground that this is the place where the cookies usually are. In fact, to pick out the specific referent of a word, the listener has to interpret the speaker's expression in light of their common ground as well (Clark, 1996). However, compared to a pointing gesture, words are more specific when used to refer to absent entities. By uttering "Cookie!" the child would be pretty specific about her intention while a point to the empty jar could refer to many things besides its absent content including the jar's colour, size or shape (Wittgenstein, 1953). The child could also point to the jar without any specific referent in mind, simply because she has been rewarded with a cookie for doing so in the past. The point itself would have no specific referent in this case. Thus, even though the study of pointing seems to be a valuable way to investigate displacement in a variety of species, inference about the intentional state of the pointer requires a precise methodology. This is especially important when investigating the cognitive processes underlying reference to absent entities. In the case of an unspecific request, there is no need to mentally represent the object of desire because there is no specific object of desire. Strictly speaking this is not even a case of reference since there is no object that is designated by the signal (Frege, 1892). On the other hand, requesting specific entities requires a representation of the desired object and a way to communicate this desire given the current physical and social context. Requesting specific *absent* entities requires the individual to represent the desired object independent of its perceptual availability along with a means of communication that elicits a representation of the desired object in another individual. In the absence of evolved or conventional signals that serve this function, individuals have to rely on objects, locations or movements that bear a referential relation to the absent object for both interlocutors. In the case of pointing, this would be representing a location as the location in which both interlocutors saw a certain object before. Representing this kind of relation between object and location might be seen as a precursor to symbolic representation proper.

While earlier studies investigated infants' use of declarative pointing to refer to absent entities (Liszkowski, Carpenter, & Tomasello, 2007), the study of imperative pointing seems to be more suitable to directly compare apes and infants using a similar setup (Bullinger, Zimmermann, Kaminski, & Tomasello, 2011). Two recent studies used an imperative pointing paradigm to investigate reference to absent entities (Liszkowski, Schäfer, Carpenter, & Tomasello, 2009; Lyn et al., 2014). Liszkowski et al. (2009) compared 12 month-old human infants and chimpanzees (*Pan troglodytes*) in their ability to use the former location of an object to request more objects after observing the interaction between two demonstrators (see supplementary material for details). Their results suggested that infants used this strategy to request more desirable objects whereas apes did not. The authors concluded that even though displacement seems not to be tied to language, the necessary cognitive abilities to engage in it only evolved in the human lineage.

Lyn et al. (2014) criticised this study by arguing that the apes' failure to refer to the absent objects was due to a methodological flaw instead of a lack of ability. They proposed that chimpanzees pointed to the hiding place of additional items within the test room rather then to the previous location of the desired object. According to Lyn et al. (2014), the study by Liszkowski and colleagues therefore only tested reference to occluded entities, not reference to absent entities. To test "true" reference to absent entities, Lyn et al. (2014) tested bonobos (*Pan paniscus*) and chimpanzees in a setup in which subjects were familiarised with food being stored in two locations while additional food items that could be requested were located outside the testing area (see supplementary material for details). The results showed that most apes pointed at least once to the former location of the food during test trials, thereby meeting Lyn et al.'s (2014) criterion for reference to absent entities.

The two studies discussed above yield contradicting conclusions. More importantly, however, neither of them tested for *reference to absent entities*. Namely, it is unclear whether subjects, apes as well as human infants, in any of the two studies intended their requests to yield a specific object (e.g. "Give me a *grape*") or whether their pointing reflected a more general and unspecific request ("Give me something" or "Do something over there"). In addition to the methodological problems discussed by Lyn et al. (2014), Liszkowski et al. (2009) offered only undesirable objects as an alternative which were most likely ignored by the subjects. There was no need to flexibly adjust the request due to contextual variations. From a functional perspective the request served to obtain a desired object but from a referential perspective it is unclear whether subjects intended this (see also Bates, Camaioni, and Volterra (1975) for this distinction). Equally damaging to the interpretation of Lyn et al.'s (2014) results is the fact that both available locations were deliberately paired with the food items and the procedure rewarded points to both locations. It is conceivable that subjects had simply learned to instrumentally point to those locations to obtain food without them intending to communicate with the experimenter about the intended referent and indeed, data showed that subjects did not differentially point to the two locations.

This means that, as far as we know, whether apes or human infants request *specific* absent entities remains untested. Building on the work of these two previous studies, we introduced the following methodological improvements. First, instead of offering a single desirable option to request, we varied the quality of the alternative option available. Crucially, we made sure that the alternative option, when presented on its own, was still desirable to the subject. The subject should only request the absent option if it is of higher value than the visible option. Second, in contrast to earlier studies we decided to use a procedure in which subjects gained direct instead of observational experience about the relevant aspects of the study.

We presented apes and 12 month-old human infants with two plates on which we placed either objects of different or the same quality. Subjects were then allowed to request these still visible objects one by one from the experimenter (E) by pointing to the respective plate. Once an option was depleted, E refilled this option with objects of the same kind multiple times. Importantly, these additional objects were stored outside the test room and were never visible to the subject. In the critical test trials, instead of refilling the depleted option, E remained seated and waited for the subject to make another request. If subjects were specific in their requests, they should only point to an empty plate when this plate previously contained objects of a higher quality than the still visible alternative. By varying the combinations of options available we ruled out alternative explanations such as associative learning or the use of simple heuristics. Furthermore, we used a within subject design for all species, so that every subject had to flexibly adjust his or her requests based on the available options.

2. Experiment 1: specific requests for absent entities by great apes

2.1. Subjects

We included 39 great apes housed at the Wolfgang Köhler Primate Research Center (WKPRC) at Zoo Leipzig in the initial sample. Three subjects (1 Bonobo and 2 Chimpanzees) had to be excluded because they did not show a clear pattern of food preference (see Section 2.3). The final sample comprised six orangutans (*Pongo pygmaeus*; Female $N = 4$), four gorillas (*Gorilla gorilla*; Female $N = 3$), seven bonobos (Female $N = 5$) and 19 chimpanzees (Female $N = 13$). The mean age of the subjects was 20.1 years with an age range from 3.9 to 48.0 years. While seven individuals were hand-reared and 25 mother-reared the rearing history of four individuals was unknown. All subjects had experience with cognitive tasks and were used to request desired food items by pointing at them. Eight of the chimpanzees also participated in the study by Liszkowski et al. (2009) seven years earlier. Participation in the study was voluntary, subjects were never food deprived at any time during the study and water was available *ad libitum*. All food rewards were given in addition to their regular daily diet.

2.2. Setup

Fig. 1 shows a schematic drawing of the setup. We tested subjects individually in a familiar rectangular enclosure within a special testing room or their sleeping quarter. We installed a transparent Plexiglas window (69 cm × 48 cm) with three small holes on the bottom (∅ 4 cm, one left, one middle one right) in the front wall of the enclosure. The holes were large enough for subjects to insert one or more fingers through them but were too small to reach through them. Two identical white plastic plates (∅ 10 cm) were placed on a table (35 cm × 78 cm) in front of the window, one plate in front of the left and one in front of the right hole (distance from hole approx. 10 cm, distance from plate to plate 35 cm, see Fig. 1).

Before a session started or after a session ended the two plates were simultaneously covered by a large plastic occluder. During training and test trials we placed food items on the plates, which the subject could request by inserting one or more fingers through the respective hole in front of each plate. The food that we used to bait and re-bait the plates was stored outside the test room and was never visible to the subject at any time. Except for the food preference test, the type of food on each plate remained the same within each session. The experimenter (E) sat on a small stool in front of the table facing towards the window. All trials were videotaped for later coding. We tested subjects in one session per day, resulting in nine test days per individual: one food preference session, four training sessions (two per food quality) and four test sessions (two per condition).

2.3. Procedure

2.3.1. Food preference and training

We administered a food preference test to each subject prior to the first training session. We presented subjects simultaneously with two food items, one on each plate, one high quality (HQ) and one low quality (LQ). Subjects had to choose the high quality item in at least 10 out of 12 trials in order to proceed to the training.

Each training session involved 12 trials. In each trial the subject was allowed to request one food item from a plate containing initially three items. After the first three trials the experimenter re-baited the plate with three items. This procedure went on until the subject had requested 12 items (see supplementary material for details). In each training session we presented the subject with only one type of food (high vs. low quality, the same as in the food preference test) on one of the plates. Each subject received four training sessions, two sessions with the high quality food items and two with the low quality food items, one of each with the food

Fig. 1. Illustration of the experimental setup used for apes in experiments 1 and 2. Subjects could request food items by inserting a finger into the hole in front of a plate. The experimenter handed over the requested items through the hole in the middle. Additional food items used for re-baiting were stored outside the test room.

on the left plate and one with the food on the right plate. The order of food types and the side were counterbalanced across subjects. In order to finish a training session, each subject had to request and consume all food items on display. If a subject did not consume all low quality food items within a training session, the low quality food option was switched and the food preference test and the training trials started anew. Together with the food preference test, this procedure ensured that both food types were desirable to the apes with a clear preference for the high quality type. Grapes were the high quality food type for all 36 subjects. For 23 subjects 5 mm thick slices of carrot and for 13 subjects small pieces of apple (approx. half the size of a grape) were the low quality food type.

This training procedure served three purposes: (a) to create the expectation that more food is available and E is willing and able to get it, (b) to establish that only the food types presented in the beginning are available within a session and (c) that pointing to the middle or the plate that never contained food are not rewarded. Please note that our procedure ensured that the experimenter handed over HQ and LQ food items equally often and was not differentially associated with one food type.

2.3.2. Test

The general setup and procedure were the same for the test and the training trials. However, unlike the training sessions, both plates were initially baited with three food items of the same type during the test sessions. There were four different constellations with respect to the baiting: (1) LQ food items on both plates, (2) HQ food items on both plates, (3) HQ food on the left and LQ food on the right and (4) LQ food on the left and HQ food on the right. These constellations resulted in two conditions: the *same* condition with the same food type on both plates (regardless of quality) and the *different* condition with different food types on both plates. We tested each subject in a within-subject design with four test sessions, one with each of the constellations mentioned above. This resulted in two sessions of the *same* condition and two sessions of the *different* condition per subject. We counterbalanced the order of constellations across subjects.

Subjects were allowed to request food items in the same way as in the training sessions. In the warm-up phase, both plates contained food. As soon as the subject requested all food items from one plate, E re-baited this plate immediately with food items stored outside the test room. However, after E had re-baited food two times and the subject emptied one of the plates again, E remained seated and the test phase began. In the test phase, only one plate contained food (after the food in the other plate had been depleted). In each test trial, the subject could point to the plate that still contained food, point to the empty plate or not point at all. Each test trial lasted 90 s or until the subject pointed. If the subject did not point after 45 s, as a reminder, E called the subject's name, slightly lifted both plates and gently knocked them onto the table before placing them back in their original position. After another 45 s without a point, E ended the test session by occluding the plates simultaneously. If the subject pointed to the plate with visible food items, E handed over one item and the next test trial started. As soon as both plates were empty the test session ended as well. If subjects pointed to the empty plate, E stood up, left the room, returned with one food item of the type that was previously on that plate and handed it over to the subject through the hole in the middle. Then the test session ended as well. The maximum number of test trials per session was three, since the maximum number of food items still visible was three. In the *same* condition, the food that was present (LQ or HQ) was the same as the food that was absent, whereas in the *different* condition, the food types differed (usually the LQ food was present and the HQ food was absent). Please note that test trials with LQ food in the *same* condition and test trials in the *different* condition were usually perceptually identical: One plate containing LQ food and one plate containing no food.

2.4. Coding and analyses

For each trial in the test sessions, we coded (1) whether subjects pointed or not (2) through which hole the subject pointed (left, right or middle) and (3) whether the subject requested absent food items or not. We defined pointing in the following way: the subject inserted one or more fingers into *one* of the holes in the Plexiglas panel so that they protruded on E's side of the panel. We did not code as pointing if the subject simultaneously inserted fingers into more than one hole at the same time or if subjects inserted a finger while E was not present. The first author coded all sessions from video. A second coder, blind to the purpose of the study, coded 25% of all sessions randomly selected together for experiments 1 and 2. There was a very high agreement of 99.6% between the two coders ($\kappa = .993$, $N = 872$, $p < .001$).

To analyse whether apes' requesting for absent food items in the test trials was influenced by the within-subject factor condition or the between-subject factors species and sex, we used a generalized linear mixed model (GLMM). This model allowed us to account for the repeated testing of the same individuals by including subject identity (ID) as a random effect into the model. Since the response variable was binary (point to absent or not) we used a binomial error structure to fit the data. All models were fitted in R (R Core Team, 2012) using the function glmer of the R-package lme4 (Bates, Maechler, & Bolker, 2012).

To assess whether the inclusion of a predictor improved the model fit we used a likelihood ratio test (LRT) implemented in the R function anova with argument test set to "Chisq". The initial full model comprised condition as within-subject effect as well as species and sex as between-subject effects and subject ID as random effect. However, since none of the gorillas requested absent food in any of the test trials, estimation of a parameter for the respective level of the predictor species was not possible. Therefore, in order to determine the influence of the factor species, gorillas had to be excluded from the data. Using the reduced sample, we found that the inclusion of the predictors species and sex did not significantly improve the fit of the model to the data (LRT comparing the two models: $\chi^2 = 2.31$, $df = 3$, $p = .51$). Therefore, we used data from all individuals for the final model and only included condition as fixed within-subject effect as well as subject ID as a random effect. We assessed model stability by comparing the estimates derived by a model based on all data with those obtained from a model with subjects excluded one by one. The results of this comparison revealed stable model parameters with respect to all predictors.

2.5. Results

All subjects pointed to one of the plates during the four test sessions. Three subjects refused to point in one of the test sessions and two subjects refused to point in two sessions. The remaining 31 subjects pointed in all test sessions. We observed a total number of 337 points. The majority of these points (321) were directed at the visible food items and only a few were directed at an empty plate (16) (see Table 1). We observed 14 points by twelve individuals in the *different* condition, 13 of which were directed at the plate that previously contained HQ food. In the *same* condition one individual pointed to an empty plate in both constellations. In three out of 16 cases, subjects pointed through the middle hole before pointing at the empty plate.

Using the GLMM described above, we found that apes' requests for absent food items were influenced by the condition (LRT, $\chi^2 = 12.61$, $df = 1$, $p = .0004$). They pointed significantly more often to the empty plate in the *different* condition compared to the *same* condition (β = 2.41, *SE* = 0.84, *z* = 2.85, *p* = .0004).

2.6. Discussion

Using an improved methodology, we were able to show that apes requested, however infrequently, absent food items. The overall rate of pointing to empty plates found in our study was rather low compared to the study by Lyn et al. (2014). This result was expected because subjects had an alternative option available, which was valuable to them when presented on its own during training sessions. Earlier studies did not offer a valuable alternative and could therefore not address the question whether apes' requests were specific. Although our procedure lowered the likelihood to point to the empty plate in general, it allowed us to systematically study *why* subjects pointed to the empty plate. Regarding this question, we found that apes requested more absent food items in the *different* condition than in the *same* condition. That is, apes preferably pointed to the empty plate when the other plate contained LQ food and the empty plate previously contained HQ food. This pattern indicated that pointing to the empty plate was indeed a flexible response by the subjects with a specific communicative goal.

If pointing to the empty plate would have been a consequence of apes simply continuing what they had done in the trial before, we should have found no difference between the two conditions. During training, we did not react to, and therefore did not reward, subjects' pointing to the empty plates. On an associative account, being rewarded for a point to an empty plate should have increased the overall number of points, regardless of condition. However, most subjects only pointed to the empty plate once. Taken together, this suggests that associative learning could not explain our results. Furthermore, even though the test trials with LQ food in the *same* condition were perceptually identical to the test trials in the *different* condition, subjects only pointed to the empty plate when it previously contained HQ food, suggesting that pointing was driven by desire for the absent HQ food and not distaste for the present LQ food. Therefore we conclude that at least some apes requested specific absent entities.

3. Experiment 2: requests for absent entities without a visible alternative

In experiment 1, most subjects did not point to the absent food during the test sessions and chose to request the visible food instead. This showed that the LQ food option was a valuable alternative indeed. However, an open question is whether those subjects who did not request any absent food items would specifically request HQ food items once the alternative was gone, too. That is, when faced with two empty plates in the *different* condition would they point to the plate that previously contained the HQ food? Furthermore, a situation in which there is no valuable alternative option available would resemble the situation subjects were faced with in the studies by Liszkowski et al. (2009) and Lyn et al. (2014). The results would therefore clarify whether the interpretation of these earlier results as unspecific requests was justified. In order to address these questions and to replicate our results from experiment 1, we conducted experiment 2.

3.1. Subjects

The same 36 subjects that participated in experiment 1 took part in the second study. One chimpanzee had to be excluded because she did not request all low quality food items during the training sessions.

3.2. Setup

The setup was identical to experiment 1.

3.3. Procedure

We used the same procedure for training and test trials as in experiment 1 with the following exception: in those trials in which the subject requested all visible food items and both plates were empty, we did not immediately occlude the plates but administered another test trial (follow-up trials). Like all other test trials, this additional test trial ended if the subject pointed to one of the plates or after 90 s without pointing (with a reminder after 45 s). Thereby, we wanted to find out if subjects would systematically request absent HQ food when the alternative LQ food was gone as well. Please note that subjects who pointed to the empty plate or refused to point for 90 s while there was still food visible earlier in the test trials did not receive this additional test trial.

3.4. Coding and analyses

We coded all trials including the follow-up trials in the same way as in experiment 1 (for reliability see Section 2.4). We analysed all trials excluding the follow-up trials using the same model as in experiment 1. This part was a direct replication of experiment 1. Additionally, we analysed the follow-up trials in which subjects pointed to one of the empty plates separately. The dependent variable for this GLMM was whether or not subjects indicated the HQ food. The model comprised condition as a fixed within subject effect and subject ID as a random effect.

The model used to analyse all trials excluding the follow-up trials was stable with respect to all predictors. The model analysing the follow-up trials was stable with respect to the fixed effect of condition but revealed considerable uncertainty of estimates for the random effect subject ID. The latter is only a minor issue since we did not interpret this predictor.

3.5. Results

3.5.1. Results excluding follow-up trials

Focusing on the original test trials (and excluding the follow-up trials), we found a very similar pattern of results between experiments 1 and 2. Namely, we observed a total number of 333 points. The majority of points (315) were again directed at visible food items and only a few were directed at an empty plate (18). There were 15 points to an empty plate by 13 individuals in the *different* condition and three points by three individuals in the *same* condition (see Table 1). All three points in the *same* condition occurred when there was LQ food on both sides. Five out of 18 points to empty plates were preceded by a point through the middle hole.

Comparing the full against the null model, we found that the frequency of pointing to empty plates was again influenced by condition (LRT, χ^2 = 10.25, *df* = 1, *p* = .0014). Subjects pointed significantly more often to the empty plate in the *different* condition compared to the *same* condition (β = 1.834, *SE* = 0.67, *z* = 2.74, *p* = .0014). Furthermore, we found a significant correlation between individuals' performance in experiment 1 and this part of experiment 2 (Kendall's tau: r_τ = .35, *z* = 2.96, *p* = .0031).

3.5.2. Results follow-up trials

In the follow-up trials all but four individuals pointed to one of the two empty plates at least once. In total, subjects pointed in 81% of trials to one of the empty plates. In the *different* condition we observed 41 points, 21 of which were used to request HQ food while 20 were used to request LQ food. In the *same* condition there were 53 points, 29 to request absent HQ food and 24 to request absent LQ food. We found no evidence that the type of food that was requested in the follow-up trials was influenced by the condition (LRT, $\chi^2 = 0.11$, $df = 1$, $p = .74$).

3.6. Discussion

We replicated the results obtained in experiment 1 in the first part of experiment 2. Furthermore, we found that individuals' performances in the two experiments were systematically related.

The results obtained in the follow-up trials highlight the importance of our methodological considerations. As a group, those individuals who did not request absent food items when there was still a valuable alternative present did not make specific requests once this alternative was gone. These results are also very similar to those reported by Lyn et al. (2014). In the test trials, they presented subjects with two empty locations and found that apes pointed to both locations equally often. Therefore, based only on the results obtained in earlier studies and the follow-up trials in the present study we would have had to conclude that apes' requests were not specific. However, given our earlier results, we can conclude that at least some apes systematically requested absent HQ food items and were therefore communicating about *specific* absent entities.

4. Experiment 3: specific requests for absent entities by 12 month-old infants

In experiments 1 and 2 we were able to shed some light on the nature of apes' requests for absent entities. However, the same methodological criticism that applies to earlier studies with apes applies to earlier studies with infants. In experiment 3, we adopted the methodology used in experiments 1 and 2 to gain insight into the specificity of 12-month old infants' requests of absent entities. We also aimed at a high similarity in the methods used with apes and infants in order to study the evolutionary (dis) continuity of the ability in question. Instead of running two experiments with infants as well we only ran a single experiment following the procedure of experiment 2.

4.1. Subjects

We tested 40 12-month old infants (20 girls, $M_{age} = 379.2$ days, $SD = 7.4$ days). They came from a middle-sized German city and were recruited from a database of children whose parents volunteered for studies on child development. Only children whose parents reported that they pointed were invited. Twenty-four additional infants were invited for the study but had to be excluded because they did not point to request any objects (11), showed no interest in the study materials or the game (3), did not complete both test sessions (6) or became fussy (4).

4.2. Setup

Fig. 2 shows a schematic drawing of the setup. The study took place in a rectangular testing room (4.30 × 4.30 m) within a child laboratory. The setup comprised two chairs facing each other (distance: 1.40 m), flanked by two platforms (length × width × height 55 × 28 × 69 cm; distance between platforms 50 cm) with a ceramic plate (∅ 20 cm) on top of each and a cylindrical container (∅ 24 cm, height 47 cm) with a funnel on top in between the two chairs. The infant sat on the parent's lap on the chair facing away from the entry door while the experimenter sat on the other. The platforms were closer to the experimenter's chair (distance 30 cm), so that he could easily reach for the objects placed on top of the plates on his left and right, while the container was placed directly in front of the infant. The interaction was structured as a game that involved throwing different kinds of objects into the container. Insertion of objects produced a rattling sound and made them disappear out of sight.

Before a session started or after a session ended the two plates were each covered by a grey cardboard box. During training and test trials we placed objects on the plates, which the subject could request by pointing at them from a distance. Additional objects were stored outside the test room behind a curtain and were never visible to the subject. All trials were videotaped for later coding.

4.3. Procedure

4.3.1. Procedural adjustments

The general procedure was modelled after the ape study (see Section 2.3). However, instead of seeing each subject repeatedly on different days, we tested each subject in two sessions on a single day. Training and test sessions were therefore combined into one session.

Instead of providing food items, we embedded the test into a game, which involved throwing objects into a container, and offered objects of different attractiveness to the infants. Pilot testing showed that colourful balls (red and blue, ∅ 5 cm) could be used as HQ objects and wooden cubes (side length 2.5 cm) as LQ objects. Instead of offering three objects per plate at a time and re-baiting the plates three times during test sessions, we offered two objects at a time and re-baited the objects only twice. These adjustments were necessary to account for infants' limited span of attention and interest while still maintaining a within-subject design. For the same reason we limited the duration of each test trial to 60 s and encouraged infants by alternately lifting both plates every 15 s to make a request.

Each subject received one test session in the *same* condition and one test session in the *different* condition. Between the two test sessions, all participants left the test room and played for approximately 5 min in a different room. The constellations (see Section 2.3.2), the colour of the balls and the order of conditions were counterbalanced across subjects.

4.3.2. Training

Prior to testing, E played with the infant in a playroom until he or she was comfortable with the situation. Together with the parent they then entered the test room and sat down on their respective chairs. Each session started with the training phase in which the experimenter uncovered the two plates, took one object from the right plate, showed it to the subject and threw it into the container. Next he repeated the same procedure with an object from the left side. Then he again took one object from the right plate and handed it over to the subject. If the subject did not immediately throw the object into the container, E encouraged the infant by shaking the container. He then repeated the same with one object from the left. As soon as both plates were empty, E *immediately* stood up, left the room and re-baited each plate with two of the same objects, which had been on the plate before. This training procedure served to familiarise the subject with the game and the objects available in the session as well as to create the expectation that more objects are available and E is willing and able to get them. Some infants refused to throw the objects into the container and offered them to either E or the parent instead. In such cases E or the parent took the object and threw it into the container.

4.3.3. Test

The warm-up phase started immediately after the four training trials. After re-baiting the plates E sat down on his chair and waited for the subject to request further objects by pointing at them. If

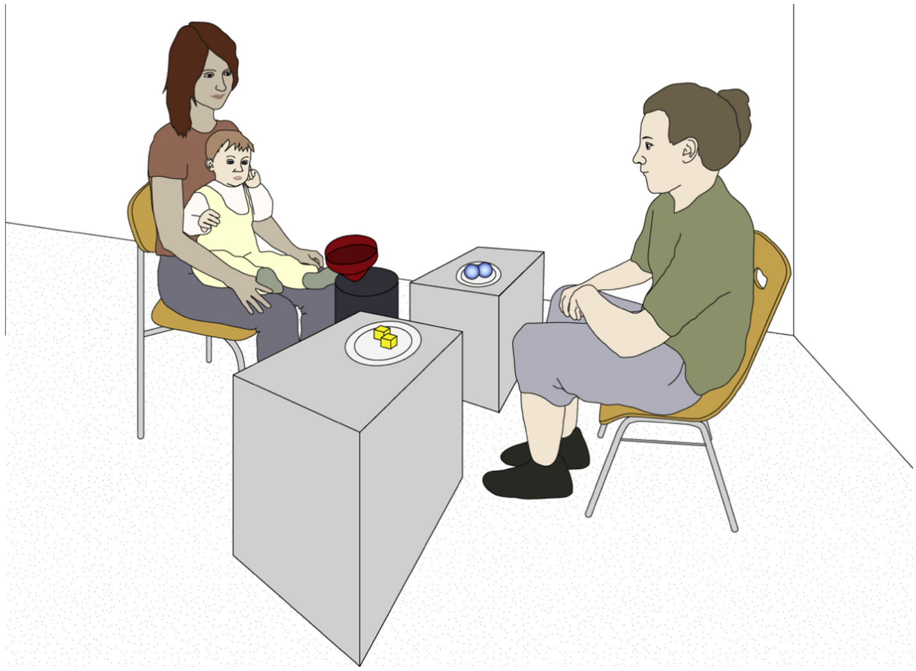

Fig. 2. Illustration of the experimental setup used for infants in experiment 3. Subjects were seated on their caregiver's lap. They could request objects by pointing at them from a distance. The experimenter handed over the requested objects through the middle. Additional objects used for re-baiting were stored outside the test room.

subjects did not point, E encouraged them to do so by drawing their attention to both plates. As soon as the subject requested all objects from one plate, E re-baited this plate in the same way as after the training trials. After the subject emptied another plate, the test phase began. The remaining test procedure was the same as in the ape study (for exceptions see Section 4.3.1). Since we followed the procedure of experiment 2, we also included the follow-up trials.

4.4. Coding and analyses

As for the apes, for every test sessions we coded (1) whether infants pointed or not (2) to where they pointed ('left', 'right' or 'other') and (3) whether the subject requested absent objects or not. We defined pointing in the following way: the subject extended at least one arm (either fully or partially), with either the index finger or the whole hand stretched out, and briefly stayed in this position. We did not code as pointing if the subject extended his or her hand into the container, simultaneously pointed to two different locations or pointed while E was away. The first author coded all sessions from video. A second coder, blind to the purpose of the study coded 25% of all sessions randomly selected. There was a very high agreement of 94.2% between the two coders ($\kappa = .899$, $N = 122$, $p < .001$).

Like in experiment 2, we analysed the regular test trials separately from the follow-up trials. To test whether infants' requests for absent objects in the first part were influenced by condition, we used the same GLMM as for the ape data in experiments 1 and 2. The inclusion of the additional predictors age (in days) and sex did not improve the fit of the model to the data (LRT, $\chi^2 = 2.84$, $df = 2$, $p = .24$).

To analyse the follow-up trials, we used the same GLMM as for the follow-up trials in experiment 2. The model used to analyse all trials excluding the follow-up trials was stable with respect to all predictors. The model analysing the follow-up trials was stable with respect to the fixed effect of condition but revealed considerable uncertainty of estimates for the random effect subject ID. The latter is only a minor issue since we did not interpret this predictor.

4.5. Results

4.5.1. Results excluding follow-up trials

All but one subject pointed during the two test sessions. Additionally, one subject refused to point in the *same* condition and four subjects did so in the *different* condition. The remaining 34 subjects pointed in both test sessions. We observed 107 points in total. The majority of these points (87) were directed at visible objects and considerably fewer were directed at an empty plate (20). Since each subject was tested only once in each condition, the number of points per condition equals the number of subjects who pointed. Fourteen infants pointed to the empty plate in the *different* condition, 13 of these points were directed at the plate that previously contained the HQ objects. Six infants pointed in the *same* condition, two of which also pointed in the *different* condition (see Table 1). In the *same* condition five points occurred when there were LQ objects on both sides while one point occurred when there were HQ objects on both sides.

The comparison of the full model comprising condition as a predictor with the null model comprising only the random effect showed a significant influence of condition (LRT, $\chi^2 = 4.46$, $df = 1$, $p = .034$). Infants pointed significantly more often to an empty plate in the *different* condition compared to the *same* condition ($\beta = 1.13$, $SE = 0.57$, $z = 2.00$, $p = .034$).

4.5.2. Results follow-up trials

Thirty-six subjects completed at least one follow-up trial and 29 subjects pointed at least once. In total, subjects pointed in 67% of the follow-up trials to one of the empty plates. We observed 14 points in the *different* condition (6 HQ and 8 LQ) and 20 points in the *same* condition (14 HQ and 6 LQ). Using the GLMM described above, we found no evidence that the type of object that was requested in the follow-up trials was influenced by the condition (LRT, $\chi^2 = 2.51$, $df = 1$, $p = .11$).

Table 1
Number of points, with number of individuals who pointed in parenthesis, to visible and absent objects per experiment, species and condition.

Experiment	Species	N	Points to absent		Points to visible	
			Condition			
			Different	Same	Different	Same
1	Bonobo	7	2 (1)	0	35	28
	Chimpanzee	19	9 (8)	2 (1)	77	88
	Gorilla	4	0	0	24	23
	Orangutan	6	3 (3)	0	20	26
	Ape total	36	14 (12)	2 (1)	156	165
2	Bonobo	7	4 (4)	1	25	36
	Chimpanzee	18	10 (8)	1	69	84
	Gorilla	4	0	0	24	21
	Orangutan	6	1	1	31	25
	Ape total	35	15 (13)	3 (3)	149	166
Follow-up	Bonobo	7	7 (5)	10 (5)	–[a]	–
	Chimpanzee	18	20 (13)	30 (17)	–	–
	Gorilla	4	4 (3)	2 (1)	–	–
	Orangutan	6	10 (6)	11 (6)	–	–
	Ape total	35	41 (27)	53 (29)	–	–
3	Human	40	14[b]	6	38	49
Follow-up	Human	40	14	20	–	–

[a] During follow-up trials, there were no visible food items available (see Sections 3.3 and 4.3).
[b] For children, the number of points equals the number of pointing individuals (see Section 4.3).

4.6. Discussion

Overall, the results for infants in experiment 3 were very similar to the results for apes in experiments 1 and 2. We found that infants systematically requested absent HQ objects more often than absent LQ objects. That is, they pointed more often to an empty plate when it previously contained HQ objects while the other still contained LQ objects than when both plates previously contained objects of the same quality. Given our partial within subject design, this pattern suggests that individual infants flexibly adjusted their pointing based on what it was that they wished to request.

If infants' pointing to the empty plate would simply reflect a tendency to continue doing what they did before, there should have been no difference between the two conditions. The test trials in the first session were the first time infants could gain a reward by pointing to an empty plate, so there was no opportunity for them to associate pointing to the empty plate with receiving a reward before. In fact, on an associative account, those infants who pointed in the first round should have also pointed in the second round, a pattern which we only observed twice. If subjects pointed in the *different* condition because they disliked the remaining LQ objects and not because they desired the absent HQ object, those subjects who pointed in the *different* condition and received the *same* condition with LQ objects on both sides should have also pointed in the *same* condition since there was no perceptual difference between the test trials in these cases. However, we only observed this pattern once.

The results from the follow-up trials again highlight the importance of a valuable alternative to determine whether or not infants request specific absent entities. As a group, those infants who did not request absent HQ objects while the alternative was still present did not systematically do so once the alternative was gone. However, given the results from the first part of the experiment, we can conclude that at least some infants requested specific absent entities.

5. General discussion

The findings of this series of experiments show that great apes and 12-month-old human infants request, however infrequently, specific absent entities (see Fig. 3). In the beginning of each test session, subjects had to decide which of the available options they desired more. After the desired option had been depleted, they had to determine whether the remaining visible option matched their desire and, if not, whether the empty location previously contained their object of desire. Only in situations in which the visible option was of lower quality than the depleted option, did subjects use the former location of the desired option to request additional items of the same kind. Overall, the rather low number of points to the empty plates indicates that the alternative we presented was indeed a valuable option to choose. Nevertheless, by systematically requesting absent HQ objects in the presence of LQ objects, subjects showed that they flexibly adjusted their pointing not only to the current perceptual environment but also to the immediate past.

Our results support the general conclusion drawn by Lyn et al. (2014) for apes and by Liszkowski et al. (2009) for infants (while not supporting their claim about human uniqueness) namely that communication about absent entities is not tied to language. However, in these earlier studies it was unclear whether a point to an empty location only served the function of requesting another item or if it was intended by the subject to refer to that item. In the former case, the subject could simply execute an unspecific communicative act that is interpreted by the experimenter as a request for the only option available. This is exemplified in our study by the results from the follow-up trials. As a group, those subjects who were confronted with two empty plates did not make specific requests. That is, they did not specifically point to the plate that previously contained the HQ objects in the *different* condition but indicated both plates equally often. Thus, it seems very likely that, at least in most cases, subjects did not point in order to request a specific absent entity in the follow-up trials, but rather pointed to get some unspecific response from the experimenter. However, please note that those subjects who requested specific absent entities during regular test trials did not proceed to the follow up trials. Unlike earlier studies, we can therefore conclude that at least some subjects made specific requests.

It is unlikely that this pattern of results is brought about by associative learning or the use of simple heuristics. First of all, all species were either discouraged or did not have the opportunity to point to an empty plate before the first test trial. Associating pointing to an empty plate with receiving a reward was therefore not possible. Furthermore, if there would have been a simple law-like connection between an action (sticking a finger through a hole in presence of the experimenter) and a corresponding result (receiving a reward), subjects should not have treated the empty plate differently depending on the visible alternative. The same is true if subjects' points to the empty plates simply reflected a tendency to repeat the last rewarded behaviour. Furthermore, the most common response in all conditions was to switch as soon as one plate was empty. If subjects simply avoided pointing to the LQ object, they should have pointed more often to the empty plate in the test trials of the *same* condition with LQ objects on both sides because they were perceptually identical to the test trials in the *different* condition. Therefore, the points to the empty bowls were most likely driven by a specific desire for the absent HQ object.

Even though the results obtained for apes and human infants are very similar, we have to acknowledge the differences between the two procedures. Apes received more training trials and also more warm-up trials compared to human infants. These differences were mainly due to a relatively fast decrease in attention and motivation in infants. The use of toys instead of food items might also have affected the motivation to request objects differently. It was therefore not possible to compare the performance of apes and infants directly to see if there might be gradual

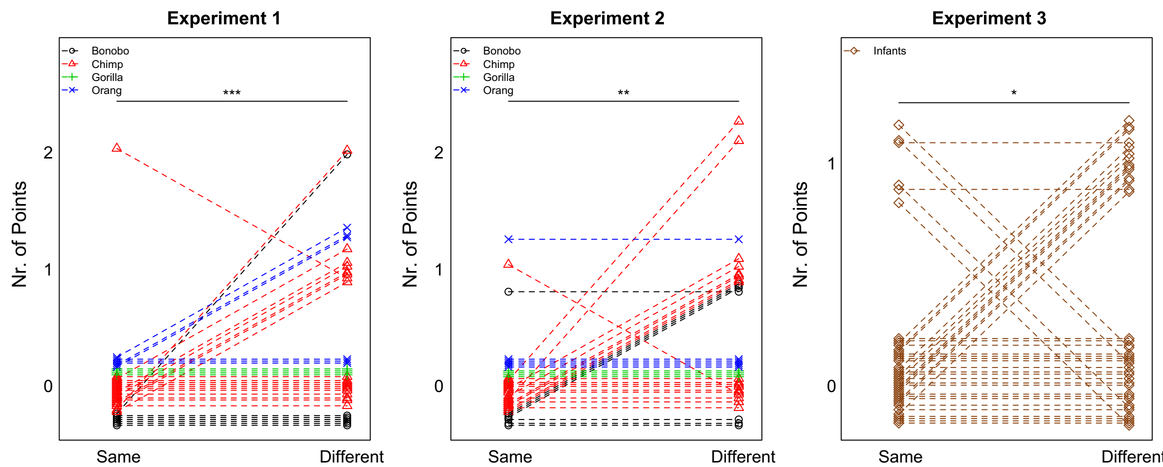

Fig. 3. Number of points to empty plates for each subject per condition and experiment. Each subject is represented by two symbols (one per condition) and a connecting line. The results of the follow-up trials in experiments 2 and 3 are not depicted in the graphs. The different types of symbols denote the different species. The maximum number of points possible per individual in experiment 3 is one because each infant only received one test trial per condition.

differences in the tendency to request specific absent entities. However, the internal structure of the experiments was the same for all species so that we can safely assume that they tackle the same underlying cognitive processes.

Despite the apparent similarities between apes and infants in the present study, apes and infants differ substantially in their use of pointing gestures. Human children start to point around their first birthday in various cultures around the world (Liszkowski, Brown, Callaghan, Takada, & de Vos, 2012) and they do so rather spontaneously (Matthews, Behne, Lieven, & Tomasello, 2012). Apes also start pointing without explicitly being trained to do so (Call & Tomasello, 1994; Leavens et al., 2004). However, they do so almost exclusively in captivity (Tomasello, 2008; but see Hobaiter, Leavens, & Byrne, 2014). Furthermore, while infants use pointing to direct the attention of others to external objects or events, ape pointing is most likely the result of a ritualized reaching process that does not involve directing the attention of others (van der Goot, Tomasello, & Liszkowski, 2013). Some of these differences might help to explain why only humans have evolved a cultural environment that allows infants to develop into proficient users of a conventional symbolic system (Tomasello et al., 2007).

Nevertheless, the results of the current study show that some of the basic cognitive processes to engage in referential communication are shared between apes and infants. That is, apes and human infants have communicative goals about specific entities that are relatively independent of the immediate perceptual environment and they are able to flexibly adjust their means of communication to a given context. Furthermore, they seem understand that a location can be used to request an absent object because the location contained the object in a previous interaction. However, based on our results, we cannot determine how detailed apes' and infants' representation of the absent entity was. Instead of representing them as separate objects with certain properties, they might have represented them in a less detailed, relational manner. That is instead of representing an absent "ball" or "grape" subjects might have represented them as "an entity that is of better quality compared to the visible one". Pinpointing the precise nature of apes and infants representations of absent entities would be a valuable task for future studies. Furthermore, it is unclear, to what extend apes and infants take into account the more social aspects of the interaction, such as the knowledge and competence of their interlocutor when requesting absent entities. Future research should address this question to better understand the role of shared experience and common ground as a basis for communication about absent entities.

In sum, the current study provides the strongest evidence to date that the ability to refer to specific absent entities in a flexible way is neither dependent on language nor something uniquely human. However, the evolutionary route to human communication and language is best understood as not just a simple addition of certain "design features". It is better to think of it as a dynamic process in which cognition and motivation interacted within the social and physical environment to yield a communicative system that is tailored to solve recurrent coordination problems.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.cognition.2015.08.009.

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