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Pointing to Nothing? Empty Places Prime Infants' Attention to Absent Objects

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People routinely point to empty space when referring to absent entities. These points to "nothing" are meaningful because they direct attention to places that stand in for specific entities. Typically, the meaning of places in terms of absent referents is established through preceding discourse and accompanying language. However, it is unknown whether nonlinguistic actions can establish locations as meaningful places, and whether infants have the capacity to represent a place as standing in for an object. In a novel eye-tracking paradigm, 18-month-olds watched objects being placed in specific locations. Then, the objects disappeared and a point directed infants' attention to an emptied place. The point to the empty place primed infants

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in a subsequent scene (in which the objects appeared at novel locations) to look more to the object belonging to the indicated place than to a distracter referent. The place–object expectations were strong enough to interfere when reversing the place–object associations. Findings show that infants comprehend nonlinguistic reference to absent entities, which reveals an ontogenetic early, nonverbal understanding of places as representations of absent objects.

Displacement, the ability to communicate beyond the immediate "here-and-now," is a defining feature of human language (Hockett, 1960). When communicating, speakers of a common language use mutually known codes, such that when a speaker says "Elephant" it will evoke a thought about an elephant, even when there is none in the surrounding space. Language is a powerful tool for acts of displacement, because linguistic codes are independent of the spatio-temporal surroundings of the communicative act.

However, one can also communicate beyond the immediate "here-and-now" without a shared linguistic code. Such acts of displacement, perhaps in the more literal sense, depend on mutual knowledge about *places*. We define places as locations in space, which are habitually or conventionally assigned to specific entities. Shoes may go to the left corner of the entrance, the key on the chest in the corridor. By virtue of directing a person's attention to an empty place, one may prime her to think about an absent entity commonly known to be in that place.

Speakers of languages with absolute frames of reference routinely refer to absent entities by pointing in the absolute direction of the places of these entities (Haviland, 1993; Levinson, 2003). In those cases, neither the entities nor their places are visible and must be inferred from the indicated direction. Such acts of absolute pointing work, because they rely on mutual knowledge about the indicated directions of places and their entities. Usually, however, absolute pointing does not distinguish between places and their referents, as these are spatially conflated. Laboratory-based investigations demonstrate how people coconstruct arbitrary locations in space as places for absent referents. For example, when asked to develop a hypothetical floor plan (Bavelas, Gerwing, Allison, & Sutton, 2011), people often engaged in scenarios of the kind "let's say the kitchen is here" while pointing to some arbitrary location in space. Once the otherwise arbitrary location was established as "kitchen", interlocutors readily pointed to that place when subsequently referring to the kitchen. Places, literally, thus serve as placeholders for objects and can be used to refer others to absent entities usually found in a place. Clark (2003) has argued that pointing and placing are the two most basic modes of anchoring abstract communication in the material world. The relevant inferences

about the referent are instigated by embedding the act within ongoing discourse and interaction (Clark & Marshall, 1981; Nunberg, 2004; Sperber & Wilson, 1995).

While studies have demonstrated the use of abstract pointing in linguistic discourse, it is currently unknown whether one can prime absent objects by directing attention to their empty places in the absence of linguistically specified information. In adults, abstract pointing is routinely accompanied by relevant linguistic information. Further, the meaning of a place is often directly established through preceding linguistic discourse ("let's say the *kitchen* is 'here'"). It is thus possible that linguistically conveyed information is necessary in the first place to instigate inferences about absent objects from spatial indications and places. However, it is equally plausible that a nonlinguistic social-cognitive understanding of interaction (Tomasello, Carpenter, Call, Behne, & Moll, 2005), or a more general understanding of representations (e.g., DeLoache, 2004), underlies the comprehension of a location as a place for an item, such that a point to the empty place becomes immediately meaningful in terms of the missing item.

Infants are a test case to this question. Infants follow others points to objects long before they speak, and a number of studies have suggested that infants comprehend verbal and gestural reference to nonperceptible entities. In most of these studies, upon hearing a known label, or following a point, infants orient to the location of a hidden referent object (Behne, Liszkowski, Carpenter, & Tomasello, 2012; Ganea, 2005; Ganea & Saylor, 2013; Osina, Saylor, & Ganea, 2012; Saylor & Ganea, 2007). Interpretations in terms of place or referent, however, cannot easily be teased apart when the referent is not absent from, but only hidden at the indicated location. It remains to be shown whether attention to empty places primes infants to attend to the absent referent object. Testing this requires a design that decouples place and referent (e.g., Liszkowski, Schäfer, Carpenter, & Tomasello, 2009). For example, in Saylor (2004), an object and its label were repeatedly introduced ("anchored") at a distinctly marked location. At test the object was removed. Upon hearing the label, 16-month-olds oriented to the distinctly marked, now-empty location. A similar phenomenon was reported when infants (at 6 months) heard sounds instead of words (Richardson & Kirkham, 2004). In both these studies, however, the labels or sounds respectively were associated either with actions on the objects (Saylor, 2004) or with visual events (Richardson & Kirkham, 2004), which may have served as discriminative cues for the actions or events at the previous locations. The studies leave open the question whether, in the reverse direction, infants understand that places stand in for objects. A recent word learning study shows that 18-month-old infants associate a novel label with an object when the label is uttered

while pointing to the object's previous, now-empty location (Samuelson et al., 2011). It is currently unknown whether the accompanying label is necessary for infants to instigate the inference from place to referent. If it could be shown that infants' attention to absent objects can be primed by a nonverbal attention-directing gesture to empty places, this would provide evidence for a nonlinguistic understanding of the meaning of places in terms of their objects. It would support the idea that infants interpret nonverbal communicative acts beyond the given perceptual information and shed new light on the emergence of the human capacity for representational communication.

In this study, we developed a new eye-tracking paradigm to investigate whether empty places prime infants' attention to absent objects. We tested 18-month-old infants as infants at this age are at the younger spectrum of nonlinguistic representational understanding (e.g., Suddendorf, 2003) but already very competent in communicating through deictic gestures, and sensitive to location information in word learning (Benitez & Smith, 2012). Infants watched an actor ostensively place one object to one side of a table, and another object to the other side of the table, repeatedly drawing attention to the places and their objects. Subsequently, both places were emptied and the actor pointed to one of the two empty places. At test, a new screen frame appeared with both objects superimposed in the central middle on a black background, that is, independent of the previous locations, and without the actor. The current design thus decoupled place and referent from each other. Our main question was whether points to empty places would prime infants' attention to the absent objects. A secondary question was whether infants would build up a lasting place–object expectation that would interfere with subsequent novel mappings. To answer our main question, infants watched in a first block of two trials two object pairs placed on two distinct places. If pointing to an empty place would prime infants' attention to the absent object, infants should subsequently look to the object that belonged to the indicated place. Regarding the secondary question, in a second block we reversed the places for the same two object pairs. If infants retained some expectations about the initial places of the objects, we expected that this should interfere with their performance in the second block.

METHODS

Participants

The final sample consisted of 20 18-month-old infants (eight females (range: 18 months, 9 days to 19 months, 9 days). Six additional 18-month-old infants were tested but were not included because of technical

failure ($N = 2$), refusal to remain seated ($N = 1$), or becoming inattentive during the experiment ($N = 3$). Parents gave informed consent for participation of their child in the study and were given a children's book or monetary compensation for their visit.

Stimuli

Stimuli consisted of four brief movies (80 sec long) that showed a female model sitting at a table (see Figure 1). The background was light gray, the model wore dark clothing, and the table was covered with a black tablecloth. At each side of the table, equidistant to the model, lay two identical purple cloths (22 × 22 cm). Two pairs of toys of different shape and color but of the same overall dimensions were used. At the beginning of each movie, the model looked straight at the camera, presented one of the two objects at about chin-height, next to her face, looked at it and back to the camera, and said twice "Look!" She wiggled the toy slightly saying "This one…", while extending her other arm touching the cloth at the far corner of the table, "… goes here" and repeated the sequence. Then she placed the object in the indicated location and shifted gaze between the camera and object once. Then she lifted the object above the location, looked at the camera and said "Here!" while placing the object back in the location. The same procedure was repeated to introduce the other object, which was placed at the other far corner of the table. Child-directed speech was used to keep the situation as natural as possible. The linguistic content was unspecific and referentially ambiguous with regard to the objects and locations.

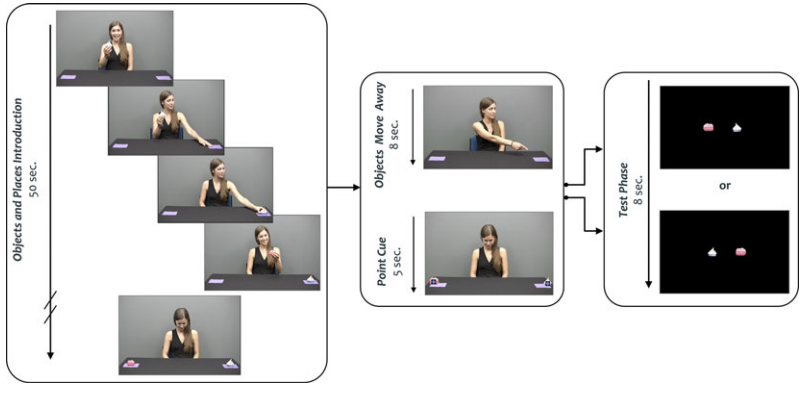

Figure 1 Depiction of the sequence of events on each trial. Only one of the two placing events is depicted.

After the placing of the two objects, the model looked down for 8 sec (see middle panel of Figure 1). While the model was looking down, the objects moved toward the corners of the image until they disappeared. To make sure infants saw the objects disappear, we superimposed small attention getters which blinked and made a sound when the objects started to move, and when they briefly stopped half-way to the edge of the image. When the objects had disappeared, the model looked up, briefly greeted the infant saying "Hi", and then "Look," while starting to look and point to one of the two locations by extending her arm and index finger across her body. The pointing phase took 5 sec during which the model alternated her gaze between the location and the center of the screen once. After that the screen turned black and the two objects were superimposed at new locations in the center of the black screen, slightly to the left and right of the midpoint of the screen, counterbalanced across trials and participants (see right panel of Figure 1). No language was used during this 8-second test event.

Two pairs of toy objects were used: (1) a yellow duck and a green ball; (2) a red rubber bus and a light blue boat. Toys rather than unfamiliar objects were chosen to reduce the load of object processing. Preliminary piloting revealed no preferences for any object. The same two pairs of objects were presented on two blocks with two trials each. The place–object pairing was flipped in the second block, so that objects assigned to the left place were now assigned to the right place and vice versa. The direction of point cue (right versus left) alternated; the order within a block was counterbalanced across participants and independent of the objects' central locations at test.

Procedure

Infants were seated in their mother's lap in front of a 17″ TFT flat-screen monitor at a distance of approximately 60 cm. Gaze was recorded using a screen-integrated eye-tracker (Tobii T120; Tobii Technology, Stockholm, Sweden). Infant's gaze was calibrated before testing using a 9-point calibration procedure (3-by-3 grid of colored circles appear in the screen sequentially). Calibration was repeated if a successful fixation was obtained for fewer than seven points.

Data reduction

First, gaze-replay movies of the infants' looking behavior were obtained using Tobii Studio software (the infant's gaze is overlaid in red over the image). Movies were inspected to ensure that infants were attending to all the critical parts of the trial: the gaze replays had to follow the placing of

both objects, the moving away of both objects, and the point cue to the respective place. Thirteen trials (16% of all trials) of ten infants were excluded because infants did not attend to one or more of these events. The remaining 67 trials were further analyzed by a custom-made excel template. Counterbalancing was not affected by the excluded trials: On 33 trials, the target appeared on one side of the screen's midpoint, in the same half of the screen in which the point had appeared, but notably at a very distinct location (see Figure 1), and on 34 trials the target appeared on the other side of the screen's midpoint, in the half of the screen in which the point had not appeared. These numbers were equally distributed across the two blocks. Two rectangular area of interest's (AOI's) were defined, each one surrounding one of the two objects on the black test screen (220 × 200 pixels). For our main measure, we determined the time infants spent looking at either AOI. We extracted infants' number of gazepoints to the AOI's. Gazepoints reflect the inbuilt Tobii measure of corneal reflections registered at a rate of 60 Hz. Each gazepoint represents a sample of data during which the fovea rested in a particular location within an AOI for at least 16.7 ms, which provides an adequate measure for the amount of looking, and which we calculated in the same way for both target and distracter AOI. The average number of gazepoints to either AOI for each block of trials was submitted to further analyses.

In addition, we calculated the duration of the first look to either AOI. While the direction of the first look should be random, the first look might already linger longer on the target than on the distracter. However, the first look duration is a very stringent, conservative measure relative to measuring cumulative looks across the test phase. To exclude cases where the eye might have moved quickly to scan the scene without fixating on an object, a look was commonly defined as a fixation consisting of a string of five or more consecutive gazepoints (equal to or longer than 83.5 ms). As a control, we also analyzed the direction of the first look: As infants could not have an expectation on which side from midline the target would appear in the new scene, they should look equally often first to the target or distracter. The measure thus also controlled for potential spatial carry-over effects from the pointing to the test phase (although note that the point was already in a very different direction from the place in the screen center where the objects later appeared).

RESULTS

A two-way Object (target versus distracter) × Block (first versus second block) ANOVA on the mean number of gazepoints showed significant

main effects for Object [$F(1,18) = 4.97$, $p = .038$; $\eta_p^2 = .33$], such that infants looked significantly more to the target than distracter, and Block [$F(1,18) = 21.22$, $p = .0001$; $\eta_p^2 = .42$], with more looking during the first than the second block. Figure 2 shows that infants looked significantly longer at the target than the distracter object in the first block [simple effects, $F(1,18) = 2.45$, $p = .024$; $\eta_p^2 = .45$]; 75% of the infants in the sample (15 of 20) looked longer at the target than the distracter in the first block (binomial sign test, $p = .041$), while in the second block 60% of the infants (12 of 20) looked longer at the target than the distracter (p = ns).

Analyses of the duration of the first look revealed that infants' first look was not significantly longer for the target object than the distracter object ($F(1,18) = 2.36$, $p = .14$). However, the data showed a pattern consistent to that observed for the number of gazepoints. In the first block of trials, the first look at the target object was on average 1.21 sec ($SD = 0.67$ sec) long and to the distracter object it was 0.95 sec ($SD = 0.64$ sec) long, while in the second block of trials, the first look at the target object was on average 0.75 sec ($SD = 0.61$ sec) long and to the distracter object it was 0.82 sec ($SD = 0.66$ sec) long. Our control analysis confirmed that the proportion of first looks directed toward the target for each block was not significantly different from chance. In the first block, infants looked first to the target in 55% of the time and in the second block in 48% of the time.

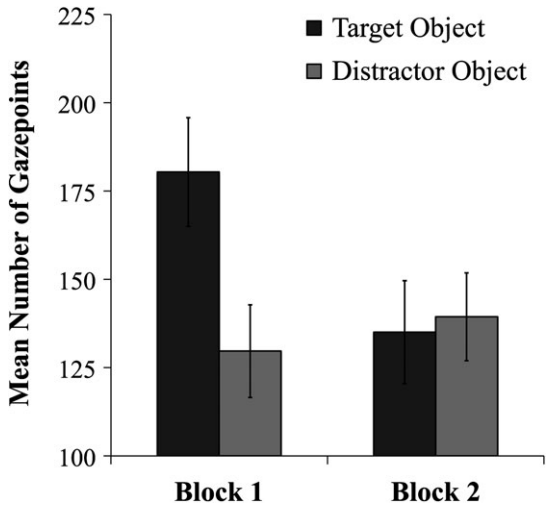

Figure 2 Mean number of gazepoints to each object in Blocks 1 and 2.

DISCUSSION

Points to empty places primed infants' attention to objects previously placed there. Importantly, the current design disentangled location and referent. Findings thus corroborate previous evidence that infants do not only follow others' directional cues, but expect these to be about specific entities. More importantly, current findings reveal an understanding of places in terms of objects, while the study excludes several alternative interpretations not invoking a notion of places. Firstly, the locations were not distinctly marked, excluding feature learning (e.g., "red car goes with red-marked location"). Secondly, at test, the objects appeared at new, central locations, decoupled from the indicated places and the agent, excluding spatial carry-over effects. The counterbalancing of the side of the objects at test, in connection with our result of a random direction of the first looks, further confirmed that the effect was not driven by spatial configuration. Thirdly, there was a choice of two objects that were counterbalanced and otherwise equally likely to be attended, thus invoking information from the preceding context as a prime to the choice. Finally, the place–object relations were not established through language, neither was the point accompanied by any disambiguating language, showing that linguistic processes are not necessary for understanding abstract pointing. In our view, then, the pointing gesture directed infants' attention to one of the two empty locations. The previously established usage of the otherwise arbitrary locations as places for distinct objects made the indication of the places meaningful in terms of the missing objects. Thus, the point to the empty place induced an expectation about a specific referent in terms of the missing object, such that infants attended in a subsequent scene more to that object than to another distracter referent. It is theoretically possible that nonsocial or exogenous cues to empty places would also prime infants' attention to absent objects; however, previous research has shown that infants do not follow nonostensive cues in the same way as communicative looks and points (Behne, Carpenter, & Tomasello, 2005; Senju & Csibra, 2008), and do not retain attention in the same way following exogenous cues (Itakura, 2001; Okamoto-Barth, Moore, Barth, Subiaul, & Povinelli, 2011).

The effect was already apparent in the first two trials, which excludes the potential role of any learning or task-inherent processes. However, when the place–object pairings were reversed in the second block of the experiment, the effect disappeared. Following our account, infants formed an initial place–object pairing which later interfered when the place–object mappings were reversed. Consistent with this interpretation, a recent study suggests that infants' knowledge about familiar objects' locations interferes

with orienting to new hiding places of these objects (Osina et al., 2012). Further, in analogy, studies on infants' word–object mapping show that infants retain the mapping over time (Woodward, Markman, & Fitzsimmons, 1994) and commonly do not accept a learnt label for another object. However, it is also possible that the lack of an effect in the second block was due to fatigue, as perhaps indicated by the general decrease of looking to the objects. One should also note that the current design followed a methodologically rigorous method alike to two-word mapping studies (Schafer & Plunkett, 1998), which is more demanding than learning only the mapping between one word and object, or one place and object.

Previous studies have paired auditory cues with visual events, such that the auditory discriminative cue triggers attention to the empty location in which the associated visual event is expected (Richardson & Kirkham, 2004; Saylor, 2004). In the current paradigm, the retrieval cue (the point) was never coupled with the object or the placing event. Further, the current design required an inference from place to object identity, rather than from auditory cue to a visual event. Our findings corroborate and extend the recent finding that infants learn a label when it is uttered in the absence of the object while attention is directed to the object's previous location (Samuelson, Smith, Perry, & Spencer, 2011). Several studies have revealed that infants interpret linguistic and gestural reference on the background of linguistic context and shared activity (Ganea & Saylor, 2007; Liebal, Behne, Carpenter, & Tomasello, 2009; Moll, Richter, Carpenter, & Tomasello, 2008). Adding to these findings, the current study reveals that infants understand locations as places for objects when interpreting nonverbal abstract points. In a more literal sense of "common ground" then, places ground nonverbal reference to absent objects in space.

Language is a powerful tool for directing others' attention to absent objects and events. Before language has emerged in earnest, the primary way of directing others' attention is through deictic gestures such as looking, showing, pointing, placing. While infants' deictic communication is bound to the space within which it occurs, the current study shows that it includes place–referent mappings which enable communication about entities beyond the immediate here and now (see Liszkowski et al., 2009). Abstract pointing is routinely embedded within linguistic communication, but the current findings show that the meaning of these gestural deictic forms of displacement is independent of language. Instead, it rests on a deeper understanding of nonverbal attention-directing actions and the usage of locations as places for objects (Clark, 2003). Infants' comprehension of locations as placeholders for objects suggests a nonverbal representational understanding that one thing can stand in for another. The

finding that attention-directing gestures can establish deferred meaning in infants hints at a developmental path from nonverbal attention-directing to nonverbal representational communication.

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