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# Communicative Function Demonstration induces kind-based artifact representation in preverbal infants

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## ABSTRACT

Human infants grow up in environments populated by artifacts. In order to acquire knowledge about different kinds of human-made objects, children have to be able to focus on the information that is most relevant for sorting artifacts into categories, Traditional theories emphasize the role of superficial, perceptual features in object categorization. In the case of artifacts, however, it is possible that abstract, non-obvious properties, like functions, may form the basis of artifact kind representations from an early age. Using an object individuation paradigm we addressed the question whether non-verbal communicative demonstration of the functional use of artifacts makes young infants represent such objects in terms of their kinds. When two different functions were sequentially demonstrated on two novel objects as they emerged one-by-one from behind a screen, 10-month-old infants inferred the presence of two objects behind the occluder. We further show that both the presence of communicative signals and causal intervention are necessary for 10-montholds to generate such a numerical expectation. We also found that communicative demonstration of two different functions of a single artifact generated the illusion of the presence of two objects. This suggests that information on artifact function was used as an indicator of kind membership, and infants expected one specific function to define one specific artifact kind. Thus, contrary to previous accounts, preverbal infants' specific sensitivity to object function underlies, guides, and supports their learning about artifacts.

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## 1. Introduction

People tend to conceptualize objects in terms of the object kind they belong to: a rock, a dog, a knife, a computer. Representing an object as a member of a kind allows one to consult stored knowledge to infer invisible properties of the object and/or predict its behavior. Representing objects as members of a kind also makes it possible to store them in short-term memory without having to preserve their idiosyncratic features. Although such a memory representation does not enable definite re-identification of an ob-

ject (in the sense of "this is the same individual as the one I saw before"), it contains sufficient information to conclude that an object of a different kind cannot be the same as the one already stored in memory. In other words, information on kind membership provides a criterion for object individuation (Xu & Carey, 2000).

In a seminal study, Xu and Carey (1996) developed an object individuation task to test whether human infants represent objects in terms of their kinds. In their paradigm, infants were familiarized to events in which two different objects (e.g., a duck and a ball) emerged one at a time from behind a screen in a way that the infants never saw the two objects simultaneously. Subsequently the screen was removed revealing either both objects or just one of them. Results showed that 12-month-old infants looked longer

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at the one-object outcome, suggesting that they expected to find two objects behind the screen, whereas 10-month-olds failed to display evidence of a definite expectation of the number of objects present. Further evidence confirmed that 12-month-olds' success in this task was based on representing objects in terms of their kind membership rather than their kind-independent visual properties. When the objects emerging from behind the screen were of the same kind but differed in non-kind-relevant properties, such as color or size, 12-month-olds did not expect to find two objects behind the occluder (Xu, Carey, & Quint, 2004). This suggests that object individuation was not the consequence of an assumption about the enduring nature of object properties. Rather, infants made a kind-based inference to the presence of two objects relying on the assumption that an object cannot simultaneously belong to two different basic-level kinds. Other studies, however, suggest that younger infants, and even non-human primates, can rely on property information alone to individuate objects in simpler tasks whose short-term memory requirements are less demanding (e.g., Wilcox & Baillargeon, 1998).

What developmental process enables 12- but not 10month-olds to use kind information in object individuation tasks? According to one hypothesis, the acquisition of basic-level kinds depends on acquiring verbal labels, such as count nouns, that map onto kind concepts (Xu, 2007). The results of an experiment that used the original Xu and Carey paradigm except that each emerging object was named by a different verbal label are consistent with this proposal (Xu, 2002). With this modification, even 9-month-olds expected to find two objects behind the screen (see also Xu, Cote, & Baker, 2005). A verbal label, interpreted as a common noun, is proposed to facilitate encoding an object in terms of its kind because it can act as an 'essence placeholder' for the kind (Xu, 2005). In contrast, no facilitatory effect on object individuation was present when two non-linguistic stimuli (a positive vs. a negative emotive sound) were used instead of the distinct verbal labels (Xu, 2002). While this result demonstrates that infants rely on more specific information than correlated auditory stimuli when using verbal labels for object individuation, it does not necessarily support the claim that verbal labeling is *unique* in its causal power of inducing kind-based representations for objects. Evaluative valence information expressed by emotive sounds is an unlikely candidate to provide information about object kinds because they do not convey information about the kind-defining properties of the object.

Are there any alternative sources that can provide kind-defining information about an object and could therefore similarly facilitate object individuation by inducing kind-based object representation? Adults normally conceive of and individuate artifacts in terms of the specific function that they were originally designed for and intended to fulfill by their creator (Kelemen & Carey, 2007). Lacking the relevant information about the history of an object, one can infer such an intended function from other types of information available, such as the shape or other functionally relevant mechanical affordance properties of the object, or its current use in goal-directed instrumental actions (Hernik & Csibra, 2009). Young infants pay atten-

tion to functionally relevant properties of objects (e.g., whether they can be used as containers: Hespos & Baillargeon, 2001) from very early on and they can be trained to encode functionally not relevant but functioncorrelated properties of novel artifacts (Wilcox & Chapa. 2004). In addition, 11- to 12-month-old infants categorize novel artifacts according to their similarity in functionally relevant properties if, and only if, they have previously witnessed the object's functional use that highlighted specific properties as relevant for the demonstrated function of the artifact (Träuble & Pauen, 2007). In fact, even 10month-olds seem to assume that object labels map onto functionally relevant dispositional properties (such as producing a sound effect) rather than onto non-function-related visual properties (such as static object shape) of novel objects (Dewar & Xu, 2009).

Although all these studies suggests that infants are sensitive to artifact function demonstrations from very early on, none of them provides evidence for representing artifacts in terms of their kind inferred from their observed functional use. We hypothesized that communicative demonstration of artifact function even in the absence of verbal labeling of the artifacts - would be sufficient to induce kind-based artifact representation in 10-month-old infants. Demonstration of artifact function is a goal-directed action that involves a causal intervention on the artifact by an agent, which manifests a specific dispositional property of the object. Most everyday tools are typically used to produce their effect on another object, an aspect of artifact use that we wanted to avoid in an object individuation task that measures infants' numerical expectations. To get around this problem, we created novel artifacts where the demonstrated causal intervention on the object resulted in the consequent manifestation of a dispositional property on the same object.

Not all events that can be analyzed in terms of cause-effect relations are function demonstrations, however, even if they involve an agent's action. We hypothesized that it is the presence of specific 'ostensive' communicative signals (Csibra, 2010, cf. Sperber & Wilson, 1995) that indicates to the infant that the instrumental action these signals accompany is, in fact, a function demonstration. In this view, it is the ostensive context which guides the infant to interpret the observed cause-effect event as representing kind-specific information about artifact function.

Recent research within the framework of natural pedagogy theory (Csibra & Gergely, 2006, Csibra & Gergely, 2009) indicates that young infants show sensitivity and preferential orientation to specific ostensive signals (such as direct eye-contact, contingent reactivity, or being addressed by infant-directed speech, see Csibra, 2010). Ostensive signals inform the addressee that the person producing them has an overt communicative intention (Sperber & Wilson, 1995) to convey new and relevant information to the addressee. While ostensive signals do not encode information about the content of the message to be transmitted, they do invoke, however, a referential expectation in their addressee. This is indicated by the finding that deictic referential gestures such as gaze-shift and pointing induce gaze-following in infants only if they were preceded by infant-directed ostensive signals (Senju & Csibra, 2008).

Furthermore, ostensive signals have been hypothesized to elicit a 'genericity bias' in the addressee to encode subsequently manifested information about a referent as expressing generic (kind-relevant) properties of the object kind that the referent belongs to (Csibra & Gergely, 2009). Note that ostensive signals, such as eye-contact, infant-directed speech, and addressing the baby by name, are regularly used in infant studies to draw the attention of the infants to the task, and were also present in earlier studies demonstrating kind-based object individuation (Dewar & Xu, 2009; Xu, 2002; Xu & Carey, 1996; Xu et al., 2005).

## 2. Experiment 1

We tested whether object individuation at 10 month of age could be facilitated by the demonstration of their function. We performed a standard object individuation task following the procedure introduced by Xu and Carey (1996). In the Communicative Function Demonstration (CFD) Condition, functional uses of two different novel objects, brought out from behind an occluder, were demonstrated sequentially. During the test trials, the occluder was lifted, revealing one or both of the objects, and infants' looking times were measured to these alternative outcomes. In the Baseline Condition, a different group of infants were presented with only the stationary displays of one or two objects.

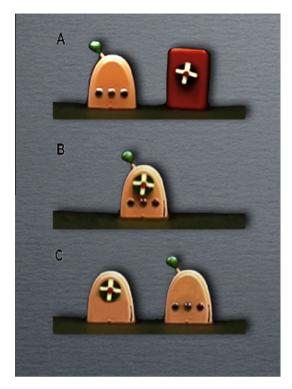
## 2.1. Method

## 2.1.1. Participants

Twenty-four 10-month-olds participated in the experiment. Half of them were assigned to the Baseline Condition (6 males and 6 females; mean age: 307 days; range: 292–324 days), the other half (5 males, 7 females; mean age: 312 days; range: 298–322 days) to the Communicative Function Demonstration Condition. Seven additional infants were excluded due to experimental error (1), fussiness (5), or inattentiveness (1).

## 2.1.2. Materials

Stimuli were presented as pre-recorded video clips on a 21-inch (53.3 cm) computer screen. The display area was 9 cm (7.4°) in height and 41 cm (32.6°) in width (further measures are given in screen size). In the middle of the display area, a red occluder (19.5 cm, 15.9°, wide, 9 cm tall) stood on a dark gray surface. One of the two objects used in the study (Fig. 1A) was a red rectangular box (4.0 cm tall, 2.7 cm wide,  $3.3^{\circ} \times 2.2^{\circ}$ ) with a green circular dial (diameter: 1.5 cm, 1.2°) attached to its upper-mid portion. A white cross was painted on the dial. Turning the dial on this object resulted in it playing a melody. The other object was a pink bell-shaped box (4.0 cm tall, 3.5 cm wide,  $3.3^{\circ} \times 2.9^{\circ}$ ) with three lights (diameter: 0.3 cm, 0.25°), each surrounded by a silver line were arranged horizontally on the lower third of the object's frontal surface. The colors of the three small lights were red, orange and green. A 1.5 cm (1.2°) long handle protruded from the upper right side of the object, ending in a green sphere (diameter: 0.9 cm, 0.75°). Pulling the handle resulted in the simultaneous flashing of all the three lights.



**Fig. 1.** Objects used in the study. (A) The two different artifacts employed in Experiments 1 and 2. Pulling the green handle of the pink object resulted in flashing the three lights on the front while turning the dial on the red object produced a short musical melody. (B) The double-function object employed in the familiarization phase of Experiment 3. The two manipulanda produced the same effects as above. (C) The two objects presented in the test phase of Experiment 3, retaining only one or the other functional feature of the object shown at (B). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

#### 2.1.3. Procedure

In the Communicative Function Demonstration (CFD) Condition, each infant received two familiarization and two test trials. In between trials, a visual attractor stimulus was presented to direct the infant's attention to the display before the next familiarization trial began. At the beginning of each familiarization trial, the infant saw the occluding screen only while hearing a greeting ("Hi baby, hi!" in Hungarian) by a female voice in infant-directed speech (2 s). Then one of the objects was pulled out from behind the screen by a hand, visible from the wrist. The object was moved along the gray surface with steady speed (4 cm/s) following a horizontal trajectory until it stopped at a position 6.5 cm (visual angle from the subject's point of view:  $10^{\circ}$ ) from the edge of the occluder (1.6 s). The object then stayed stationary in this position for a period of 11.8 s during which the function demonstration on the object was repeated twice. The function demonstration consisted of the hand operating the manipulandum (the dial or the handle) on the object, as a result of which an effect was produced (turning the dial produced a melodic sound effect, or pulling the handle made the lights to flash three times). After the first function demonstration, the hand withdrew from the object and disappeared at the top edge of the display area. Then it returned and demonstrated the same operation again. Following the second function demonstration, the hand pulled the object back behind the screen following the same trajectory as when the object was originally pulled out from behind the occluder (1.6 s). During the 1.5 s interval, when no object was visible, the same female voice was heard saying in infant-directed speech, "Watch this!". The second object then was brought out from behind the screen by the hand to the other side of the stage. Two function demonstrations were then performed by the hand exactly as on the other side before, except that it involved the other object. Finally, the object was pulled back by the hand to its starting position behind the screen. At the end of the familiarization trial, an attractor stimulus was presented, and when the infant was looking at the display screen again, the second familiarization trial began.

The first phase of the test trials was identical to the familiarization trials. The second phase of the test trials started right after the second object was placed behind the occluder. The occlusion lasted for 5 s, during which the same female voice greeted the infants in infant-directed speech ("Hi baby, hi!"). Then the hand appeared from above, grabbed the occluder and removed it by lifting it upwards and revealing either one or two objects behind it. Infants' looking times were measured from the appearance of the Outcome (one object or two objects). Test events were terminated when the infant looked away from the computer screen for more than two consecutive seconds. The minimum looking time was 1 s and the maximum was 120 s. The order of presentation of the objects during familiarization, the presentation sides (left or right) of the two objects, the order of test trials (single-object display first and two-objects display second, or vice versa) and the identity of the object presented in the one-object test display were all counterbalanced across participants. In the Baseline Condition, infants were presented with two object presentation trials, which were identical to the second phase of the test trials in the CFD Condition.

Infants sat on their parents' lap 70 cm from the monitor, with eye level approximately at the center of a computer monitor in a dimmed room. Parents were instructed to keep their eyes closed and not to interact with the infants

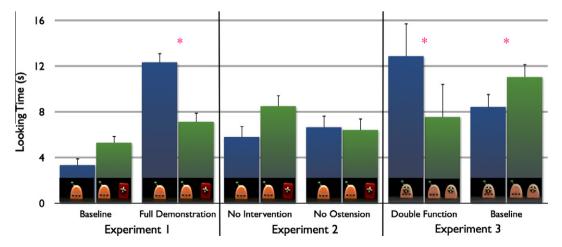
during the full length of the measurements. An experimenter watched the infants' looking behavior on a separate computer screen connected to two video cameras (one placed above the monitor focusing on the infant's face, the other placed in one corner of the room) and registered the length of their visual fixation to each test event by pressing a key on the keyboard. The whole procedure was videotaped for offline coding of looking times. A second coder recoded 50% of the video-records of the test events. Inter-rater reliability was high (r = .97).

## 2.2. Results and discussion

Preliminary analyses found no effects of presentation order during familiarization or test trials, the identity of the object presented in the one-object test display, and the presentation sides (left or right) of the two objects in the two-object display. Subsequent analyses were therefore collapsed over these variables.

Looking times during the test phase were analyzed by a  $2 \times 2$  ANOVA with Outcome (one vs. two objects) as within subject factor and Condition (Baseline vs. CFD) as between-subject factor (Fig. 2). We found a marginally significant main effect of Outcome ( $F_{1,22} = 4.029$ , p = .057,  $\eta^2 = .155$ ) and a significant interaction between Condition and Outcome ( $F_{1,22} = 19.649$ , p < .001,  $\eta^2 = .472$ ). Planned t-tests were performed within each condition. Infants tended to look longer at the two-object outcome in the Baseline Condition ( $t_{11} = 1.943$ , p = .078;  $M_{one-object} = 3.33$  s, SD = 2.09 s;  $M_{two-object} = 5.29$  s, SD = 3.01 s), while they looked significantly longer at the one-object outcome in the CFD Condition ( $t_{11} = 4.120$ , p = .002;  $M_{one-object} = 12.31$  s, SD = 2.78 s;  $M_{two-object} = 7.11$  s, SD = 3.91 s).

These results were corroborated by non-parametric tests showing that 11 of the 12 infants in the CFD Condition looked longer at the one-object outcome (p = .006, sign test), while 9 out of 12 infants looked longer at the two-object outcome in the Baseline Condition (p = .146, sign test). The difference between the two groups was significant (p = .003, Fisher's exact test).



**Fig. 2.** Looking times in the test trials of Experiments 1–3, contrasting one vs. two objects as outcomes. Error bars represent standard error of the mean. Asterisks mark statistically significant differences (p < .05).

Our findings indicate that even without verbal labeling of the objects, communicative function demonstration alone can induce kind- or property-based object individuation in 10-month-old infants. Earlier findings suggested that there are prelinguistic conceptual representations of at least some *global* kinds at this age, such as humans vs. non-humans (Bonatti, Frot, Zangl, & Mehler, 2002) or self-moving agents vs. inert objects (Surian & Caldi, 2010), that allow for the individuation of objects even when spatio-temporal evidence or linguistic labeling is not available. Our results are the first, however, to demonstrate the existence of conceptual representations of basic-level kinds in the domain of artifacts that can support object individuation in 10-month-olds without differential verbal labeling or spatio-temporal evidence.

Function is an abstract and kind-defining property of artifacts, which cannot be directly perceived or equated with specific perceptual features. The kind-specific function of an artifact can only be inferred from its potentially relevant physical properties (like shape), its re-occurring instrumental use observed in specific types of goal-directed activities, or its observed culturally conventional uses. The fast and efficient identification of the function of an artifact, however, is best served by communicative demonstration of its kind-specific functional use. Such demonstrations of artifact functions include two types of crucial information: (a) ostensive signals that indicate to the observers that the instrumental actions are performed 'for' them (Csibra, 2010), and (b) causal intervention on the artifact by an agent, which reveals its dispositional properties.

## 3. Experiment 2

Experiment 2 tested whether the facilitatory effect of function demonstration on object individuation in 10month-olds found in Experiment 1 is dependent on (a) the presence of the ostensive signals (in this case, infantdirected speech) that preceded the demonstration, or (b) the causal manual intervention on the object that resulted in the effect. Accordingly, this experiment included two conditions, in which we removed from the demonstration one or the other of these types of information. In the Non-Ostensive Presentation Condition (NOP), the infantdirected greeting that preceded the manual function demonstrations in Experiment 1 were replaced by a nonhuman melodic sound generated to match the surface acoustic parameters of the original ostensive stimulus. In the No Casual Intervention Condition (NCI), the ostensive signals of Experiment 1 remained unchanged, but infants observed the protruding parts of the objects to be moving by themselves contingently with the display of the behaviors that served as 'effects' in Experiment 1.

## 3.1. Method

## 3.1.1. Participants

Twenty-four 10-month-old infants participated in this experiment: 12 in the Non-Ostensive Presentation (NOP) Condition (8 males, 4 females; mean age: 310 days; range: 296–319 days), and 12 in the No Causal Intervention (NCI)

Condition (5 males, 7 females; mean age: 305 days; range: 296–315 days). Eleven additional six subjects were lost due to experimental error (2) fussiness (5) and inattentiveness (4).

#### 3.1.2. Materials

The same objects were used as in Experiment 1 (Fig. 1A).

## 3.1.3. Procedure

The procedure of the Non-Ostensive Presentation (NOP) Condition was identical to that of the CFD Condition in Experiment 1 except that the ostensive signals were replaced by synthesized auditory stimuli from the pitch and rhythmic intonation pattern of the original speech tracks played backward. The length and intensity parameters of the ostensive signals were preserved.

In the No Causal Intervention (NCI) Condition we retained the ostensive signals but removed manual intervention from the demonstration presented in the CFD Condition. After the hand brought out an object from behind the occluder, it left the display area and the manipulandum on the object then started to move by itself (the dial turned or the protruding handle extended further outward) while these events were accompanied by the same effects (music or light flashes) as in the CFD Condition. Following the second self-animated movement and its effect, the hand reappeared and pulled the object back behind the screen.

The whole procedure was videotaped for offline coding of looking times. A second coder recoded 50% of the videorecords of the test events. Inter-rater reliability was high (r = .92).

## 3.2. Results and discussion

Preliminary analyses found no effects of presentation order during familiarization or test trials, the identity of the object presented in the one-object test display, and the presentation sides (left or right) of the two objects in the two-object display. Subsequent analyses were therefore collapsed over these variables.

A 2 × 3 ANOVA on the looking times during the test phase with Outcome (one vs. two objects) as a within subject factor and Condition (Baseline vs. NOD vs. NCI) as between-subject factor yielded a significant main effect of Outcome ( $F_{1,33}$  = 4.252, p = .047,  $\eta^2$  = .114) because the infants looked longer to the two objects than to one ( $M_{one-object}$  = 5.25 s, SD = 3.32 s;  $M_{two-object}$  = 6.73 s, SD = 4.34 s, see Fig. 2). There was no interaction between Condition and Outcome ( $F_{2,33}$  = 1.536; p = .230,  $\eta^2$  = .085).

Comparing looking times of the NOP and CFD (Experiment 1) Conditions in a  $2 \times 2$  ANOVA with Outcome as the within subject other factor resulted in a main effect of Outcome ( $F_{1,22} = 9.535$ , p = .005,  $\eta^2 = .302$ ) and a significant Outcome  $\times$  Condition interaction ( $F_{1,22} = 7.898$ , p = .01,  $\eta^2 = .264$ ). We found no difference in the looking times to the one- vs. two-object outcomes in the NOP Condition ( $t_{11} = 1.990$ , p = .846).

A similar analysis with the NCI and CFD Conditions resulted in a significant interaction between Condition and

Outcome ( $F_{1,22} = 17.131$ , p < .001,  $\eta^2 = .438$ ). In contrast to the CFD Condition, infants tended to look longer at the two-object that the one-object outcome in the NCI Condition ( $t_{11} = 1.886$ , p = .086;  $M_{one-object} = 5.80$  s, SD = 3.41 s;  $M_{two-object} = 8.50$  s; SD = 5.64 s).

Non-parametric Fisher's exact tests confirmed that the looking time patterns in the NCI Condition significantly differed from those we found in the CFD Condition (p < .001), and tended to do so in the NOP Condition (p = .069) as well.

These results suggest that both the presence of manual causal intervention and the presence of ostensive-communicative signals are necessary prerequisites of object individuation based on artifact function at 10 months of age. In other words, while observing a causal agent's use of an artifact to achieve a specific effect allows for interpreting the event as a means-end instrumental action, the observation of current functional use, in and of itself, does not commit the infant to automatically represent it as being the inherent kind-specific functional property of the object that is representative of the artifact kind that the object belongs to. To assign such a kind-based representation to the observed function, the infant also needs to be ostensively informed that the observed use is presented as a communicative demonstration to manifest the kind-specific function that the artifact and its kind are 'for'.

Such a conclusion is consistent with the proposal that kind-based object representation is specifically facilitated by ostensive communicative demonstration (Csibra & Gergely, 2009). Nevertheless, the above experiments have still not demonstrated unequivocally that object individuation is achieved in this task by representing the objects in terms of their kinds. This is so because in Experiment 1 infants could have achieved object individuation just by encoding and comparing the two observed artifacts in terms of their different visual features. In other words, the ostensive function demonstration might simply have played the role of facilitating this featural processing rather than specifying function-based criteria for object individuation.

## 4. Experiment 3

In the final experiment we tested whether demonstrated function alone, in the absence of a difference in static visual object features, can support object individuation in 10-month-old infants. Most aspects of Experiment 3 were identical to Experiment 1. However, this time we demonstrated the two different functional uses on a single object. This object was created by fusing the two artifacts presented in Experiment 1 into one object that contained all the function-relevant features that were involved in the two functional uses demonstrated in that study. The new artifact could therefore be used for either of the two different functions: turning the dial on its front induced a melodic sound effect, while pulling its handle on its side resulted in the lights on its front to flash (Fig. 1B). We wanted to have a strong test of the hypothesis that the ostensively triggered function-based assignment of two different artifact kinds overrides the purely feature-based

encoding of the double-function object. Therefore, in our two-object test display we presented two novel objects that were different not only numerically, but also in terms of features from the single artifact used for the function demonstrations. One of the objects possessed the specific function-relevant features that were involved in one of the demonstrated functions, however, it lacked the features related to the other function. The other object showed the opposite pattern of selective feature match (see Fig. 1C). We hypothesized that ostensively induced function-based kind representations may involve selective feature-binding of those function-relevant features that the demonstrated function involves and highlights. On this account we expected that the two novel objects that selectively possess the different kind-relevant features in terms of which the two functional kinds are represented, will induce the illusion of having been already seen during familiarization.

## 4.1. Method

## 4.1.1. Participants

Twenty-four 10-month-olds participated in the experiment; 12 of them were assigned to the Baseline Condition (7 males and 5 females; mean age: 309 days; range: 294–319 days), and 12 of them to the Double-Function Demonstration Condition (8 males, 4 females; mean age: 306 days; range: 294–317 days). Three additional subjects were excluded because of experimental error (1) or fussiness (2).

## 4.1.2. Materials

Only one object was used in this study, which was a fusion of the two objects used in Experiments 1 and 2. This object was almost identical to the pink bell-shaped box, but the green circular dial of the red rectangular box was attached to the middle of the pink object. Thus, an object with two functions was obtained: turning the green dial on the object caused a melodic sound effect, and pulling the handle caused its lights to flash.

## 4.1.3. Procedure

The Double-Function Demonstration (DFD) Condition was identical to the CFD Condition of Experiment 1 except that the same object emerged from both sides of the screen during familiarization and the first phase of the test trials (Fig. 1B). However, different manipulanda were operated and different effects ensued at the two sides of the occluder screen. During the second phase of the test trial, when the occluder was lifted up, infants either saw one object, identical to the one used in the familiarization and the first phase of the test trial, or two objects: the pink bell-shaped box with three lights and a long handle but without the dial, or the pink bell-shaped box without the lights and the handle, but with the dial the middle of the object (Fig. 1C). Order and size of presentation were counterbalanced the same way as in Experiment 1. In the Baseline Condition, infants were presented with two object presentation trials corresponding to the second phase of the test trials in the DFD Condition.

The whole procedure was videotaped for offline coding of looking times. A second coder recoded 50% of the videorecords of the test events. Inter-rater reliability was high (r = 0.90).

#### 4.2. Results and discussion

Preliminary analyses found no effects of presentation order during familiarization or test trials or of the presentation sides (left or right) of the two objects in the two-object display. Subsequent analyses were therefore collapsed over these variables.

A  $2 \times 2$  ANOVA with Outcome (one vs. two objects) as within subject factor and Condition (Baseline vs. DFD) as between-subject factor on the looking times during the test phase resulted in no main effects but a significant interaction between Condition and Outcome  $(F_{1,22} =$ 19.488; p < .001,  $\eta^2 = .470$ ). Infants looked longer at the two-object outcome in the Baseline Condition ( $t_{11}$  = 2.741, p = .019;  $M_{one-object} = 8.44$  s, SD = 4.05 s;  $M_{two-object} =$ 11.04 s, SD = 5.81 s), while they looked significantly longer at the one-object outcome in the DFD Condition  $(t_{11} = 3.560, p = .004; M_{one-object} = 12.86 \text{ s}, SD = 9.98 \text{ s};$  $M_{two-object}$  = 7.54 s, SD = 8.21 s) (Fig. 2). These results were corroborated by non-parametric tests showing that 11 of 12 infants looked longer at the two-object outcome in the Baseline Condition (p = .006, sign test), while 11 of 12 infants in the DFD Condition looked longer at the one-object outcome (p = .006, sign test). The difference between the two groups was significant (p < .001, Fisher's exact test).

The results of Experiment 3 replicated those of Experiment 1 despite that fact that the two functions were demonstrated on the very same object. In fact, infants' looking pattern suggests that the two featurally novel test objects appeared to match their memory representation of the familiarization events, while the single test object (even though it was identical to the one they had seen during familiarization) resulted in an apparent violation-of-expectation effect. This suggests that infants did not encode the object during the familiarization events simply in terms of its overall visual features. One possibility is that infants selectively retained the representation of at least some kind-relevant features that were involved in the different function demonstrations. They represented these as the kind-specific properties of two separate artifacts that they inferred to be present. In this case, the two novel test objects matched both infants' kind-based numerical expectation and their expectation about the kind-specific visual features of the artifact kinds inferred. Alternatively, after having inferred the presence of two separate artifacts, it may have been only this numerical expectation that the infants retained in their short-term memory. This latter interpretation would correspond to the notion of individuation as outlined in the object indexing framework (see Káldy & Leslie, 2003; Leslie, Xu, Tremoulet, & Scholl, 1998; Tremoulet, Leslie, & Hall, 2000) according to which "the object index does not represent any of the properties of the entity at which it points" (Leslie et al., 1998, p. 10) as opposed to identification, where featural information is 'bound' to the object index.

In sum, our finding makes it unlikely that infants individuated the objects they had seen purely on the basis of their visual properties. Rather, it was the functional information about artifact kinds conveyed by the communicative demonstration of only one of the functions of the double-function object at a given time that was indicative of the presence of two objects rather than one. In other words, as a result of the communicative function demonstrations, the artifacts in the event became represented in terms of their kinds, which, coupled with the assumption that basic-level artifact kinds are defined by a single essential function, produced the illusionary inference to the presence of two objects behind the occluder.

## 5. General discussion

It has been shown that verbal labeling facilitates object individuation even at 9 months of age, while visual information about different static object properties in itself fails to induce an inference to the presence of two objects (Xu, 2002, 2007). Xu hypothesized that language, through the power of common nouns, which refer to object kinds, plays a specific causal role in establishing kind representations for objects. The results of Experiment 1 indicate that representational kind assignment is not a unique causal property of language, as non-verbal demonstration of artifact function alone can also induce kind-based representation of objects in 10-month-olds.

The common causal property of linguistic labeling and function demonstration is that both are capable of identifying directly the kind that an object belongs to. Other types of information, like emotional valence, visual features, or tactile properties, can also contribute to the recognition of objects, but they do not determine their kind membership. The results of Experiment 3 suggest that infants did not rely purely on visual object properties when inferring the presence of two objects behind the screen. Had they done so, they should have expected to find only a single object there because the visual properties of the double-function object remained unchanged throughout the whole demonstration phase. Thus, two different demonstrated functions, just like two different verbal labels (Xu, 2002), were sufficient to induce the setting up of two 'object files' (Kahneman & Treisman, 1984) in the absence of any other supporting correlated information. This illusion provides evidence that infants: (a) used artifact function as an indicator of kind membership, and (b) expected that one specific function would define one specific kind.

The question of how infants represent functional properties of objects and what information is necessary to set up such representations requires further studies. However, our results clearly demonstrate that it was the distinctive demonstrated functions of the artifacts that young infants exploited to discriminate between them. Had they simply relied on the revealed dynamic dispositional properties of the objects, or on the saliently different musical vs. light effects produced, they should have also succeeded in the No Causal Intervention Condition of Experiment 2. The fact that a 10-month-olds individuate artifacts only when they are observed being used instrumentally in goal-directed

human actions strongly suggests that what the child is looking for when facing a novel artifact is information about object function (Träuble & Pauen, 2007). Furthermore, infants appeared to expect a one-to-one mapping between functions and artifacts, suggesting that an essentialist construal of artifact kinds (considered to be a late achievement in cognitive development, see Kelemen & Carey, 2007), may constitute the source rather than the outcome of children's early learning about human artifacts (Hernik & Csibra, 2009).

The other type of information that seems to be necessary for triggering function-based object individuation in 10month-olds is provided by ostensive-communicative signals, such as infant-directed speech. While previous studies suggested that before 12 months differential verbal labeling is necessary for object individuation of basic-level object kinds (Xu, 2002), in the present study the kind-based object individuation effect in 10-month-olds was induced by ostensive function demonstration alone, i.e., without the two objects being verbally labeled when presented. This suggests that it is the ostensive communication of some kind-defining property (such as verbal labeling or function demonstration) that facilitates kind assignment under 12months rather than linguistic labeling per se as was previously proposed (Xu, 2007). This conclusion is in line with the fact that in earlier studies the verbal naming of the objects was delivered in an ostensive manner.

How do such communicative signals contribute to object representation in terms of function-based kinds? Ostensive signals set up a communicative context that indicates to the child that he or she is being addressed by the demonstrator. Such contexts have been shown to trigger referential expectation in infants (Senju & Csibra, 2008) and have been proposed to induce a 'genericity bias' leading infants to anticipate that the upcoming manifestation will convey kind-relevant (semantic) information about the referent (Csibra & Gergely, 2009). This anticipation will allow the infants to interpret the demonstrator's intervention and its effect as an optimally formulated communicative act to reveal the most relevant information about an artifact (its kindspecific function) rather than reflecting idiosyncratic usage or an accidental by-product. The finding that in the absence of ostensive signals no object individuation was induced (Experiment 2) indicates that, while the mere observation of current object use is potentially (though not necessarily) informative of the kind the object belongs to, at 10 months of age it is not sufficient for infants to interpret it as the proper function of the object. When the same function demonstration is observed within an ostensive-communicative context, however, 10-month-olds do interpret the manifested function as indicative of an artifact kind. In this case, the effect of functional information on artifact representation was so strong that it even overrode perceptual information as demonstrated in Experiment 3.

In sum, we have shown that – within the domain of artifact understanding – function demonstration can induce kind assignment and object individuation in 10-month-old infants even in the absence of linguistic labeling. This effect, however, only occurs in an ostensive-communicative context, which induces an expectation of kind-relevant information to be demonstrated.

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