
Nonverbal Generics:

Ostensive Communication Aids Kind-Based
Representation of Objects and Acquisition
of Generic Knowledge in Infancy

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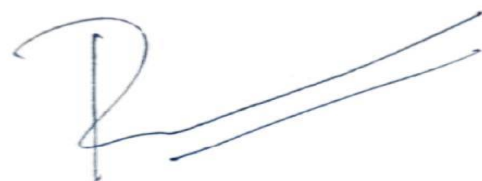
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Abstract

Humans can acquire generic knowledge from each other directly, via linguistic communication. This thesis reports studies that demonstrate that nonverbal ostensive communication can induce kind-based representation of objects in preverbal infants. Such representations license information conveyed about the objects to be bound to their kinds thus aiding one-shot acquisition of generic knowledge. Chapter 1 summarizes previous work on infants' representation of objects and sensitivity of ostensive communicative signals and raises our hypotheses on how the latter modulates the former. The study reported in Chapter 2 investigated whether nonverbal ostensive reference, mediated via deictic gestures, is sufficient to establish kind-based representations of familiar objects. We found that 9-month-old infants, who do not spontaneously form kind-based representations of objects, are successful at an individuation task with distinct objects of familiar kinds when the objects are ostensively referred. However, they fail if the objects are from the same kind but differ on kind-irrelevant features, such as color. These findings confirmed the hypothesis that ostensive referential communication can induce kind-based representation of exemplars of object kinds that are known to infants. Chapter 3 reports a set of experiments that explored whether ostensive demonstration of a dispositional property of an object is encoded as generic property. Eighteen-month-olds were tested on their inclination to extend the demonstrated property to other exemplars of the same kind even after encountering a counterexample – another object without the property. We found that the infants who received ostensive demonstration displayed resistance to counterevidence, a signature of having acquired generic knowledge about the given kind of objects. In contrast, the infants who had received non-ostensive demonstration reacted the counterevidence as if they extended the property to other exemplars via inductive generalization. This study also explored the role labels play in generic knowledge acquisition and inductive generalization. Chapter 4 investigated whether ostensive reference plays a role in how linguistic labels are promptly linked to object kinds instead of to the specific object that is labeled. The results suggest that ostensive reference prompts infants to represent novel objects by opening a kind placeholder to which predicates, such as labels, can be bound. These findings shed light on the existence of a phenomenon that we have dubbed 'nonverbal generics': human infants are predisposed to interpret nonverbal ostensive communication akin to how sophisticated language users interpret verbal generic statements. Such interpretational mechanisms allow young infants to rely on knowledgeable others, who engage them in pedagogical interactions, to accumulate knowledge about culturally shared concepts, such as generic properties of object kinds.

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Chapter 1

General introduction

1.1 Nonverbal Generics

Most stories are told with words, but they can sometimes be communicated with objects too. In 2010, The British Museum chose to tell the story of human civilization through a selection of 100 artefacts from various periods, spanning over two million years. How, one might wonder, can we tell stories through objects? For Neil MacGregor, former director of The British Museum, and leader of that project, artefacts carry messages in them:

“I'm going to tell this story exclusively through the 'things' that humans have made, all sorts of 'things', carefully designed and then either admired and preserved or used, broken and thrown away. I've chosen just a hundred objects from different points on our journey – from a cooking pot to a golden galleon, from a Stone Age tool to a credit card... because it carries all the different kinds of messages across the millennia, signals from the past if you like, that 'things' can communicate to us...” [Neil MacGregor, A history of the world in 100 objects]

But how is it possible to tell stories using objects, if each object in its existence represents only itself. Obviously, to be able to tell stories, objects like words, have to be symbols that can represent much beyond the immediately perceptible object in itself. And indeed, as we walk through a museum observing the artefacts on display, we see those objects as symbols that tell stories that go beyond their own specific existence: they convey to us relevant facts about how people who used not just a specific object lived, but about the lives of people who used objects of its kind. For instance, amongst the 100 objects at this exhibition was a bird-shaped pestle, dated approximately 4000 years ago, which inhabitants of Papua New Guinea used to grind food. The discovery of this artefact, a common culinary object, allowed anthropologists to infer that the use of tools for food processing was already part and parcel of the cultural knowledge of that civilization. Just as the pestle from Papua New Guinea, artefacts in general can be a glimpse into the intentions of their creators, the purpose and use of that kind of artefacts, and the impact this kind of artefacts had on their users' lives.

In our daily lives, we rarely come across objects that give us insight into ancient history, but they can still tell us something beyond itself. The 3D-printing machine at the university library may not convey information about lives of the students who use it like the pestle tells about old civilizations, but it gives us information about how artefacts of this kind are operated, and for which purpose it was built. Importantly, when the library assistant demonstrates how to operate said machine, we learn not only how to operate this particular

machine, but at the same time we learn about all other 3D printers of the same kind.

Although we only perceive and engage with specific objects at any given time, when learning new information about these particular objects, we routinely take this information to apply to any other object belonging to the same kind. In other words, through individual tokens we are able to acquire generic knowledge about an object kind. Consequently, it seems that we could be communicated to about a single object yet learn about its entire kind.

Imagine a second scenario in which the librarian did not explain to you how the 3D-printer works, but you happen to be in the library and observe a student operating it. Though you were not given instructions about the machine, you should be able to infer from the student's behavior what the machine is used for and how to operate it. If one day you come across another identical printer, you would likely know how to use it based on what you observed the student doing. In this scenario, your knowledge about how to operate the new printer is based on your past observation of how a particular printer was used, under the assumption that this piece of knowledge can be generalized to other machines of the same kind. If you happen to attempt to print with the machine and fail, despite having operated it the same way the student did, you will likely ask yourself what may have gone wrong. You could assume the student has used it incorrectly; or you could question whether the printer is a different kind from the one that you observed being previously used; but you could also wonder whether that way of operating the machine was specific to that very device. Unlike when the library assistant explained you how to use the printer, failure to use the machine properly in this second scenario is more likely to prompt questioning whether your generalization to a novel machine was accurate or warranted to begin with. Of course, if you were to witness similar machines being operated in the same way over multiple occasions, your confidence about what is common to 3D printers would increase, and you would be more certain about generalizing these to other machines of its kind.

Inductive reasoning through encountering multiple exemplars can be, however, time consuming and thus inefficient. A far more efficient route to acquiring generic knowledge is when they are communicated to us by knowledgeable others via generic statements. For example, the librarian can tell you: "3D printers have an ON/OFF button on their back". In such statements, the information conveyed is taken to apply to the whole kind, and is straightforwardly encoded as generic, rather than merely generalizable. A signature difference between generic and generalized information lies in their resistance to counterevidence. Unlike *inductive generalizations*, which are constantly revised and updated in light of new evidence due to the very mechanisms they were originally created with, *generic* information is insensitive to evidence countering the already acquired knowledge. This is because generic information

acquired via generic statements is not culled from the statistical prevalence of particular features within a kind, but it is interpreted as stemming from the cumulative cultural knowledge shared among epistemically trustworthy social others. The assumptions undergirding generic statements thus lead learners to disregard counterevidence, even when statistical information is overwhelmingly against the generic statement (Kushnir & Gelman, 2016; Cimpian Brandone, & Gelman, 2010; Brandone, Cimpian, Leslie, & Gelman, 2012). While generic statements are a useful fast-track to generic knowledge, their resistance to counterevidence is perhaps one key factor that leads to the acceptance of many prejudices expressed as generic statements such as, 'Girls like pink,' 'Muslims are terrorists,' and 'Africans are athletic', despite the fact that we probably have plentiful evidence to the contrary (Haslanger, 2011; Leslie, 2017).

Perhaps the reason we readily accept and hold onto to generic knowledge conveyed by others is that representing each object simply as an individual, and learning about each individual object one-by-one before we have accrued enough evidence to generalize to their kind, is not only cognitively arduous and time consuming but also a redundant and inefficient strategy when one can directly represent kinds and learn generic knowledge from others' communication. Furthermore, the inefficiency of the inductive pathway towards generic knowledge becomes particularly evident for non-obvious properties with high trial-and-error discovery costs, such as, for instance, the toxicity of particular food items. For instance, one cannot learn about a lethal mushroom by eating one, but this opaque information about the mushrooms can be easily communicated via generic statements. Similarly, individual exploration fares particularly poorly in the domain of technology, as this includes products of cumulative cultural evolution. The complex functioning and the non-obvious properties of technology are more efficiently communicated by knowledgeable others than discovered through individual trial-and-error (Csibra & Gergely, 2006; Boyd, Richerson, & Henrich, 2011; Moore, 2016).

However, since this form of knowledge transmission depends on linguistically conveyed generic statements, it is only available to proficient users of language. Older children have the opportunity to learn generic information such as 'octopuses have three hearts,' 'the death cap mushroom is lethal', 'magnets stick to iron' from generic statements even without having observed or experienced these facts themselves (Cimpian, Brandone, & Gelman 2010; Cimpian & Markman, 2009). Such a form of generic knowledge acquisition seems to leave out preverbal infants, relegating them to the less efficient and time-consuming mechanism of inductive generalization. This seems perplexing, given the vast amount of information humans

acquire within the first few years of life, and how socially and epistemically reliant on others preverbal infants otherwise are.

The theory of Natural Pedagogy (NP) proposed that, even before language skills emerge, children are sensitive to a suite of ostensive communication signals such as eye contact, infant directed speech, and being addressed by the infant's own name, that indicate that the addressees are being directly communicated to by another, and that these signals can already cue them to consider information thus conveyed as kind-relevant and generalizable (Csibra & Gergely, 2009; 2011). Such a mechanism implies that, in ostensive communication, infants are able to identify information that can be extended to other exemplars of the same kind, allowing the learning to progress much faster than if the infants had to have multiple experiences to observe recurring common features that could be considered generalizable. Importantly, what Csibra and Gergely claimed was not that the ostensively conveyed information would be interpreted as generic in a single instance of communication, as it is with verbal generics statements – but that information thus conveyed would have a stronger inductive generalization potential, allowing infants to skip over multiple instances before determining that a property is generalizable.

Verbal generic statements, on the other hand, are directly taken to be generic as opposed to generalizable. That is, when information is encoded as generic, it is represented as information pertaining to a kind, instead of as information about specific exemplars that can be then generalized to other exemplars. The difference here is between generic knowledge, which can then allow for deductively inferring about individual kind members, and inductive generalization, which proceeds in the opposite fashion, from learning about a particular and then inferring to the kind. Importantly, what this difference points to is that when encoding is about kind-encompassing generic knowledge, the individual is irrelevant, and the information is directly linked to the kind while. In contrast, in inductive generalization encoding about the individual is a part of the process.

Despite the theoretical claim that ostensive communication simply increases the generalizability of the information conveyed, some studies that tested the NP proposal seemed to instead indicate that ostensive nonverbal reference too is interpreted as an indication of kind instantiation. These studies show that infants had a strong tendency to interpret information conveyed in ostensive contexts to be about kind-relevant features. Even when no information about the ostensively referenced object is singled out, infants sometimes take ostensive reference to an object to be a cue to encode its kind-relevant rather than transient features, such the number (Chen et al. 2011; 2012), the location (Yoon et. al., 2008; Marno, 2014), or the immutable function (Hernik & Csibra, 2015) of the object. Furthermore,

information conveyed through ostensive demonstrations seems to be privileged over statistical evidence, much like information communicated via generic statements (Marno & Csibra, 2015). Relatedly, 2-year-olds and 4- to 5-year-olds disregard counterevidence about previously ostensively demonstrated functions, continuing to expect the function to hold for new exemplars of the category – a signature of having acquired generic knowledge (Butler & Markman, 2012; Butler & Tomasello, 2016).

In light of these considerations, previously we proposed that nonverbal ostensive communication can serve the function of *nonverbal generics* by licensing a generic interpretation of ostensively communicated information, whereby the referred-to object serves as a symbol of its kind (Csibra & Shamsudheen, 2015). The studies presented in this thesis directly investigate implications derived from this proposal for the acquisition of generic knowledge in infancy. Before presenting these studies, I shall first review evidence bearing on the issue of ostensive referential communication as a potential vehicle for generic information. In the subsequent sections, I will discuss: (1) infants' early sensitivity to ostensive signals; (2) their learning and interpretation of deictic gestures as referential signals; (3) how ostensive-referential signal may support kind-based encoding; (4) what the interpretation of information conveyed via ostensive demonstrations and generic statements have in common; and finally (5) the ways in which the proposal about nonverbal generics can, and will be, tested.

1.2 Ostensive Signals

Considerable evidence indicates that infants are sensitive to a number of ostensive signals soon after birth. Infants are not only preferentially attuned towards conspecifics making eye-contact, communicating in infant-directed speech, or calling them by their own name, but they also interpret these signals as evidence that they are the recipients of an intentional communicative act by a communicator. Below, I will review developmental findings suggesting an early sensitivity to ostensive signals, which cannot be adequately accounted for by low-level attentional capture.

1.2.1 Eye Contact

Establishing direct eye contact with others is an ostensive signal that indicates mutual attention and readiness to communicate. Evidence indicates that young infants have innate eye-detection mechanisms in place, and that they preferentially orient towards and attend to individuals engaged in eye contact with them. Soon after birth, newborns prefer to look at a face with open eyes than a face with closed eyes (Batki, Baron-Cohen, Wheelwright,

Connellan, & Ahluwalia, 2000). Moreover, when choosing between face stimuli exhibiting direct or averted gaze, newborn infants preferentially attend to the former (Farroni, Csibra, Simion, & Johnson, 2002). A similar effect was also seen with schematic faces (Farroni, Pividori, Simion, Massaccesi, & Johnson, 2004), thus indicating that infants do not merely react to the presence of eyes but are specifically sensitive to eye contact. This is further corroborated by evidence that newborns' preference for open eyes is specific to upright face stimuli (Farroni, Johnson, Menon, Zulian, Faraguna, & Csibra, 2005; Farroni, Johnson, & Csibra, 2004). The selectivity of this preference, despite the infants' extensive experience with caregivers' faces in non-upright orientations (e.g., during breast-feeding), has been proposed to indicate an innately specified sensitivity to face-to-face direct communication (Csibra, 2010). Importantly, infants do not show only enhanced attention to eye contact, but seem to be positively engaged towards such stimuli, as evinced by their increase of smiling when eye contact is established (Caron et al., 1997) and decrease when eye contact is lost (Symons et al., 1998), even if adults continue to respond contingently to the infants throughout this emoting exchange (Hains and Muir, 1996).

1.2.2 Motherese

If eye contact is an ostensive signal in the visual modality that even neonates show preferential sensitivity to, human speech is an auditory signal that infants can be attuned to already in utero. Studies indicate that newborns have a preference for the mother's over a stranger's voice, thus suggesting that they have been familiarized to mother's speech during pregnancy (Kisilevsky et al., 2003; 2009). Given these precocious abilities, it is unsurprising that young infants are able to discriminate between speech and non-speech stimuli, and show a preference for the former (Vouloumanos & Werker, 2007; Vouloumanos, Martin, & Onishi, 2014). Across different cultures and languages, adults are known to modify their speech pattern when addressing infants (Fernald et al., 1989). Infant-directed speech (IDS) register also known as 'motherese' is characterised by higher and more variable pitch, wider intonation contours, drawn out elongated vowels, slower speech rate and longer pauses between words compared to adult-directed speech (Kitamura & Burnham, 2003). Since speech, unlike direct eye contact, does not single out the addressee of the signal, IDS has been proposed as an infant-specialized ostensive signal that makes it manifest to the infant that she is being communicated to (Csibra, 2010). Indeed, just as infants show an early preferential sensitivity for eye contact, two-day-olds preferentially attend to a person talking in IDS over another

using adult-directed speech (ADS) (Cooper & Aslin, 1990). Importantly, newborn infants not only show a preference towards IDS but also exhibit different EEG patterns when processing IDS vs. ADS (Háden et al., 2020). Six- to 13-month-olds show increased neural activity when presented with IDS compared to ADS (Zangl & Mills, 2007; Lloyd-Fox, Széplaki-Köllőd, Yin, & Csibra, 2015). Moreover, infants at 4.5 to 9 months show a preference for IDS over ADS even when the speech stream is in a foreign language (Werker et al., 1994). A further indication that IDS also recruits attention to the communicator is that 3- to 5-month-olds show increased looking when presented with IDS compared to ADS (Kim & Johnson, 2014).

1.2.3 Own Name

Another ostensive signal which makes manifest who is the intended addressee of a communicative act is calling someone by their own name. Infants by around 4.5 months of age recognize and listen longer to their own names over similar sounding distractors matched for stress patterns (Mandel, Jusczyk, Pisoni, 1995; Newman, 2005). By around 5 months, infants show increased attention to objects presented on a screen after being called by their own names (Parise, Friederici, & Striano, 2010). Moreover, six-month-olds exhibit heightened neural activity when called their name compared to other names (Imafuku et al., 2014). Unlike direct eye contact and IDS, sensitivity to proper names requires learning that the corresponding acoustic stimulus is associated to contexts in which the infants themselves are referred to. This difference likely explain why infants are sensitive to their own names significantly later than to eye contact and IDS. Importantly, when interacting with infants, caregivers often produce these ostensive signals in conjunction with each other. By paying attention to their own names in a context in which infants have been already singled out as designated addressees of a communicative episode via IDS and eye contact, infants can robustly learn that their names also act as ostensive signals (Csibra, 2010). Thus, although certain ostensive signals may be innately specified, others may be learned in the context of early communicative interactions (Wu et al., 2014). This flexibility allows infants to develop sensitivity to a repertoire of culturally relevant ostensive signals which could allow them to recognize culturally idiosyncratic instances of direct communication from potential social partners. Recognizing when they are the recipients of a deliberate communicative act helps infants sets the stage for preferentially attending to and learning the information thus conveyed.

1.3 Ostensive Referential Signals

Communication is usually about something out there in the world, something going beyond the dyad of the communicator and the recipient. However, ostensive signals by themselves do not refer or have informative content. Soon after the first months of life, caregivers begin presenting infants with various aspects of the world via deictic referential gestures such as gaze shifts and pointing (Striano & Stahl, 2005). However, while we adults interpret these gestures as referential signals, these are arbitrary actions that hold no inherent referential meaning (Tomasello et al., 2007). Nevertheless, we have an expectation that these are not random, seemingly meaningless acts like tapping one's foot (Vouloumanos, Martin & Onishi, 2014). But what imbues only certain acts with an expectation of referentiality? Two properties common to referential signals be noted: (1) they tend to be directed away from the Self towards a target, and (2) they are couched in communicative contexts. It is likely the communicative context which these behaviors are embedded in that leads to the expectation that they are referential signals.

It seems obvious that infants are predisposed to attend to acts that function as referential signals for adults. But this does not indicate that they understand gaze shift as a referential act in itself (Butterworth & Jarrett, 1991). It has been proposed that infants begin without an expectation or understanding of referential content from these seemingly arbitrary actions and follow gaze shifts and pointing merely because these behaviors act as attentionally orienting stimuli (Corkum & Moore, 1998; Deak et al., 2014). Others instead have proposed that infants are predisposed to expect reference from what we adults understand as referential signals (Csibra & Gergely, 2006; Macnamara, 1982; Waxman & Gelman, 2009). However, that still requires a recognition of the communicative instances in which such referential acts may be performed (Csibra, 2010). As shown earlier, infants preferentially orient towards signals that in adults function to make manifest who is the addressee of a communicative act. Csibra and colleagues (Csibra & Gergely, 2006, Csibra, 2010) proposed that ostensive signals allow infants to detect communicative intentions from other people and creates expectations about accompanying or subsequent actions from these sources. One such expectation is that of referentiality, which allows accompanying or subsequent deictic acts to be interpreted as singling out specific referents of the communicative episode. In the sections below I review evidence supporting this claim and later discuss what such referential expectations could be.

1.3.1 Gaze Shift

We frequently and spontaneously follow gaze. This tendency is enhanced if gaze shifts are preceded by direct eye contact and other ostensive signals, as in that case gaze shift not only indicates another's attentional shift towards a target of interest but can also be interpreted as a signal to establish joint attention towards an object. Even newborns are faster at detecting targets on a screen when they appear in locations cued by gaze (Farroni et al., 2004). Four- to 5-month-olds are faster at producing saccades to peripherally presented targets when they have observed someone producing a gaze shift to that location (Farroni et al., 2000). Another study showed that this effect is observed only when the gaze shift is preceded by direct eye contact (Farroni et al., 2003). Similarly, 6- to 8-month-olds overtly followed an adults' gaze shift towards one of two visible objects, but only if the shift was preceded by ostensive signals: eye-contact or motherese (Senju & Csibra, 2008; Hernik & Broesch, 2019, see also Deligianni et al., 2011). While these results indicate that ostensive signals are crucial for communicative behaviors to be interpreted as referential, others have championed the idea that ostensive signals are in fact mere attention enhancers to events that follow their production (Gredebäck, Astor, & Fawcett, 2018; Szufnarowska, Rohlfing, Fawcett, & Gredebäck, 2014).

However, ostensive reference not only leads infants to follow gaze but also to expect a referent at the cued location. Csibra and Volein (2008) presented 12- and 8-month-olds with an ostensively communicating adult gazing at one of two locations, occluded from the infant's perspective. At test, a curtain came down to hide the adult, while the occluders moved aside to reveal an object behind one of the two locations. Both 12- and 8-month-olds looked longer at the empty location if it corresponded to the one gazed at. The results were interpreted to indicate that infants had understood the ostensive gaze shift as a referential signal and came to expect the location gazed at to feature a possible referent. Furthermore, infants also seem to encode and process ostensively referenced targets better than targets that, despite being similarly perceptually available, have not been gazed at by an ostensive adult (Reid, Striano, Kaufman, & Johnson, 2004; Reid & Striano, 2005; Michel, Pauen, & Hoehl, 2017; Okumura et al., 2020). For instance, Wahl, Michel, Pauen, and Hoehl (2013; see also Okumura et al., 2013) tested the differential effects of ostensive reference versus non-social attentional cueing to objects. Four-months-olds were allowed to watch a person who made eye contact with them and then gazed at one of two objects. Upon being shown the two objects again, infants looked longer to the uncued object, and also produced an increased negative central event-related potential (ERP) amplitude associated with increased orientation to novel stimuli. While it may not be surprising that the uncued objects received less attention and was processed less

relatively to the cued object, this difference only emerged when the gaze shift of an ostensive communicator did the cueing. When exposed to a non-social and non-referential cue (i.e., a toy car that turned towards either object), infants did not show differential response to the cued or uncued object. If attentional effects alone resulted in better processing of the cued object, then any kind of attentional cues should have shown the same effect as ostensive reference.

Relatedly, a recent study directly compared how the interpretation of an adult's gaze shift is affected by preceding ostensive signals compared to a non-ostensive attention-enhancing behavior. Following up on Senju & Csibra (2008), Okumura et al. (2020) tested if ostensive signals preceding gaze shifts are necessary to induce infants to follow gaze. The authors found that 9-month-olds followed gaze towards a target when the gaze shift was preceded by ostensive signals (direct gaze or IDS) as well as non-ostensive, but attention-grabbing, cues, such as the actor shivering, or a beep playing while the actor's mouth was immobile or moving. Noteworthy, Okumura and colleagues found that while non-ostensive signals can also trigger gaze following, infants showed enhanced processing and preference for the target object only when gaze shifts to the target objects had been preceded by ostensive signals. Thus, while drawing attention to the actor before the gaze shift did get infants to attend to her action, it did not prompt them to pay attention to the target of her gazing behavior. Ostensive signals, on the other hand, prompted infants to follow the actor's gaze and to encode the object she gazed at, possibly because the infants interpreted the gaze shift as an ostensive referential act. This result suggests that the effects of ostension cannot be reduced to those of other attentionally enhancing cues, and that ostensive signals help framing the interpretation of deictic gestures as referential signals.

1.3.2 Pointing

Pointing is another deictic referential signal that infants are sensitive to from very early on. Like referential looking or gaze shifts, infant sensitivity to pointing is also modulated by the presence of ostensive signals. Within ostensive contexts, infants as young as 4 to 5 months of age will follow dynamic pointing gestures (Rohlfing, Longo, & Bertenthal, 2012). Even at 12 months of age, infants comprehend static images of a pointing hand directed at objects as a referential cue but only when presented with an ostensive signal, for example, a female voice saying 'look there' (Daum, Ulber, & Gredebäck, 2013). In an ostensive hiding game with a live interactive partner, 12-month-old infants, comprehended pointing as a referential signal that indicated where an object was hidden (Behne et al., 2005; 2012). Relatedly, another study

demonstrated that deictic gestures such as pointing are taken as referential signals only when they are produced within ostensive contexts (Gräfenhain et al., 2009). In this study, 14- to 18-month-olds were tested in an overhearing context, where an experimenter interacted ostensively with an assistant, and then pointed to the location of a hidden toy in one of two containers on a table top. The infants were then allowed to search for the toy. Both 14- and 18-month-olds succeeded in retrieving the toy from the right location, showing that they were able to use the ostensive pointing gesture as a reference to the object. However, infants failed to retrieve the object when the experimenter's interaction with the assistant and the subsequent pointing were non-ostensive.

1.3.3 Speech

Human vocalizations have been traditionally bestowed privileged status among referential signals. Importantly, human speech is perhaps the earliest form of communicative signal that infants are exposed to, already in utero (Moon, Lagercrantz, & Kuhl, 2013; May et al., 2011). Neonates show a preference for human speech over non-speech sounds (Vouloumanos & Werker, 2007) and prefer their mother's voice over that of a stranger (DeCasper & Fifer, 1980). Several studies suggest that from early on infants take words to have referential meaning. For instance, 3- to 4-month-olds form an object category when multiple objects are presented with a common label, but not when they are paired with a tone sequence. In this study, infants were initially presented with a familiarization phase, where multiple exemplars from a category were accompanied by either words or tones. When presented with an exemplar from the familiarized category and a novel-category exemplar at test, only infants who heard the common label showed a novelty preference, looking longer at the latter, indicating that the label provided allowed them to form a category composed of the common features of the exemplars presented (Ferry, Hespos, & Waxman, 2010). This study indicates that even before infants begin to comprehend language, they interpret words to have referential meaning that convey information about category-relevant properties. Many other studies with infants of different ages have similarly showed that words are treated as communicative signals imbued with referential expectations (for a review: Waxman & Gelman, 2009).

Other studies, however, indicate that infants learn that words are referential signals by virtue of being presented together with ostensive signals. For instance, three-month-old infants tested on a similar paradigm as used by Ferry and colleagues (2010), showed sensitivity to lemur vocalisations as referential signals by performing on the categorization task just as

well as infants presented with human vocalizations (Ferry, Hespos, & Waxman, 2013). Since lemur vocalisations are also communicative signals, these results were taken to suggest that infants might have innately specified sensitivities to a range of vocal communicative signals as referential signals. Another study utilizing the same paradigm supports this interpretation. Six- and 12-month-olds failed to form a category when tones instead of words were presented along with multiple exemplars (Fulkerson & Waxman, 2007). But, noteworthy, when these tones were presented to the infants as potential referential signals by being embedded in a communicative exchange between two adults, infants used them to form categories. Ferguson and Waxman (2016) exposed 6-month-old infants to an event featuring two adults communicatively interacting with each other, one through English and the other through tones. After watching this event, infants were able to use tones in the categorization task. The authors interpreted the results as showing that even non-speech stimuli can acquire a referential function when they are used within communicative contexts.

1.3.4 Referential Expectation

Research on a range of deictic acts such as gaze shift, pointing, and speech supports the proposal that ostensive signals create a referential expectation from ostensive communicators, inducing infants to interpret deictic gestures as referring to relevant information conveyed to them. In sum, infants come to learn that a host of deictic behaviors have referential functions by virtue of being paired with ostensive signals, owing to the innately specified characteristic these signals have in inducing referential expectations.

1.3.5 Decoding Ostensive Reference

Preverbal infants can be informed about the world by participating in triadic interactions. Within these, infants comprehend that deictic gestures and words carry referential content. The common-sense interpretation of this process is that infants interpret communicated information as being about the here and now, with referential signals highlighting and picking out referents available in the common ground between infant and communicator (Tomasello, 2008; 2014). Often, however, we are not communicating about episodic content. For instance, when a museum curator points to an artefact and says “The astrolabe is much more than just a scientific instrument, it’s also a symbol of knowledge” (Silke Ackerman, Episode 62 of ‘A History of the World in 100 days’), we know that she is not referring to that particular astrolabe, but to all astrolabes. We comprehend that she is referring to the immediately perceptible astrolabe as a symbol of its kind.

At 3 months of age, before they can even parse words from a stream of speech, infants seem to already interpret communicative events in a similar fashion, recognizing that words refer beyond the specific exemplars being labelled (Fulkerson & Waxman, 2013). Is it possible that nonverbal ostensive referential signals such as pointing, holding up, or demonstrating the function or use of an object can also be interpreted as referring not just to the immediate referent (i.e., the particular object manipulated), but to its kind? This seems to be a rather counter-intuitive notion, given that deictic gestures often highlight properties of referents that are immediately and episodically relevant, such as their location. However, several studies indicate that infants are biased to interpret ostensive deictic gestures as highlighting kind-relevant and enduring properties of a referent, rather than episodic and transient features (Yoon, Johnson & Csibra, 2008; Okumura, Kobayashi, Itakura, 2016).

Yoon, Johnson and Csibra (2008), for instance, introduced 9-month-olds to novel objects in two different events. In one, infants were presented with an experimenter who engaged them ostensively before pointing to an object out of the experiment's reach. In the other, the experimenter attempted to reach for the same object in a non-ostensive manner. Object and experimenter were then hidden by a screen and a curtain, respectively. After a 5 s delay, the screen was removed to reveal either the same object in the same location (no-change outcome), the same object in a different location (location-change outcome), or a different object in the same location (identity-change outcome). Infants in the communicative (pointing) condition detected a change in identity but not a change in location, while infants in the non-communicative (reaching) condition showed the opposite pattern. Evidently, communicative reference biased infants to encode the object's enduring identity features instead of its episodically relevant information such as its location, which previous studies showed infants to be more sensitive to (Mareschal & Johnson, 2003; Simon, et al., 1995; Wynn & Chiang, 1998; Xu & Carey, 1996). Similar results were also found with adults, when in an array of 5 objects, one was highlighted by being non-communicatively reached for or communicatively pointed at. The array then was briefly removed from the screen and reappeared with a small change: either the location of the object's was shifted, or it was replaced by a novel object. As with infants, adults were more likely to detect a location change in the non-communicative reaching condition. Conversely, in the communicative pointing condition they were more likely to detect the identity change (Marno et al., 2014). Thus, it would seem that communication not only enhanced attention to kind-relevant features, but also had the effect of decreasing attention or memory to other episodic features of the singled-out referent.

Another type of information that has episodic relevance and can be assumed to be highlighted by deictic reference is the number of objects that are being referred to. As with location, numerosity is also ignored when referents are highlighted in an ostensive context. In a study, nine-month-olds, were presented with sets of two or three objects by an ostensive or non-ostensive experimenter before the objects were occluded. When the objects were revealed after a short delay, only infants who had received the non-ostensive presentation looked longer to a change in numerosity. Infants who received the ostensive presentation, on the other hand, looked longer to a change in the kind of objects composing the set (Chen et al., 2011; 2012).

These studies suggest that infants interpret the referent of an ostensive signal to go beyond the particular object highlighted. Despite the fact that ostensive reference is mediated via deictic gestures physically yoked to physically immediate targets, ostensive reference induces a bias to ignore the target's episodic properties, such as location and numerosity, and to encode kind-relevant information instead.

However, this proposal should not be taken as suggesting that infants cannot represent, or be informed about, particular objects. Our claim is that the default interpretation of ostensive reference in young infants would be about the object's kind unless other information indicates otherwise. Such information could be gleaned from the communicative context, like in a hide and seek game, which makes it manifest to the infant that deictic reference is to be interpreted as informing about the location of a specific hidden object (Aureli, Perucchini, & Genco, 2009; Behne, et al., 2005). Although infants are sometimes presented with idiosyncratic information, such as proper names or peculiar and non-generalizable artefact properties, a large proportion of our communication with infants and children tend to be about kinds, making thus a kind-biased processing of communicative reference a sensible interpretive default. This default might, of course, produce false positives, unless contextual cues, such as contrastive information, can mark the information as non-generic. For instance, children take labels provided in referential contexts as proper names only in the presence of another object of the same kind with a different name (Hall & Rhemtulla, 2013; Gelman & Taylor, 1984). In sum, we suggest that in ostensive referential contexts the default is to map information to kind, making the immediate referent a temporary symbol of its kind. Such a mapping creates the potential for nonverbal generics, conveying kind-relevant knowledge without words.

1.4 Ostensive Reference Triggers Kind-based Representation

In the previous sections, I reviewed evidence suggesting that ostensive communication makes infants encode kind-relevant features of novel objects (e.g., identity) over their transient attributes (e.g., numerosity or location: Yoon et al., 2008; Chen et al., 2011; Okumura et al., 2016). Importantly, the effects of ostensive communication cannot be accounted for by enhanced attention to the objects, since the failure of encoding kind-relevant properties of objects cued by non-social actions or attention-getters demonstrates (Reid, Striano, Kaufman, & Johnson, 2004; Reid & Striano, 2005; Michel, Pauen, & Hoehl, 2017; Wahl, Michel, Pauen, & Hoehl, 2012). The preferential encoding of kind-relevant properties that ostensive referential signals induce, we contend, is evidence that these, despite tied to a ‘physically immediate’ target, are in fact deferred reference to the object’s kind (Csibra & Shamsuddeen, 2015).

Prima facie, this claim seems to go against evidence suggesting that infants are unable to represent objects in terms of their kinds – even when the object is a familiar one, for which infants likely had experience with multiple tokens of the kind – unless labelled. In an influential study, Xu and Carey (1996) showed that 12-month-olds presented with two different kinds of familiar objects (a ball and a duck) that emerged from and retreated behind an occluder, one at a time (so that infants never saw these two objects at the same time), expected two objects behind the occluder when this was raised. Importantly, this expectation was restricted only to objects belonging to different kinds, but not to objects differing merely in shape, size, color, or a combination of these features (Xu, Carey, & Quint, 2004). Following up on these studies, Xu (2002) showed that at 9 months, an age in which infants failed to individuate objects of different kinds in the original Xu and Carey’s study (1996), infants proved able to individuate two objects when these were labelled with two kind names. These results indicate that, while at 12 months of age infants can spontaneously use kind information to individuate objects, at 10 they are capable of exploiting kind information only when explicitly provided by labels. Xu (2005) proposed that labelling the objects facilitated kind-based encoding for 10-month-old infants, aiding their success in the individuation task. Ten-month-old infants, who are otherwise unable to individuate even familiar objects when presented without labels, can successfully individuate these objects provided with distinct names (Xu, 2002). Relatedly, nine-month-olds who observed an experimenter looking into a box while uttering “I see a wug, I see a dax” expected two different kinds of objects in the box, as opposed to infants who hear

the very same label repeated twice, indicating that they interpreted different labels as referring to different object kinds (Dewar & Xu, 2005). On these premises, Xu (2012) proposed that words are symbolic references to kind that can trigger kind-based representations. This proposal is well aligned with the fact that kinds are not spatiotemporally defined entities but can only be represented symbolically. Since words are symbolic devices that do not require anchoring onto a particular physical object to act as referential signals, they represent ideal vehicles to convey symbolic kind reference (Lupyan & Bergen, 2016). In contrast, deictic ostensive reference seems to be a poor vehicle for a reference to kind, given that, by its nature, it is intimately yoked to the spatiotemporally contingent properties of the object being referred to.

However, a study from Futo et al. (2010) suggests that ostensively presented information can trigger kind-based representation in 10-month olds, just as count nouns can. In this study, infants were presented with familiarization trials in which they saw two objects come out from behind an occluder, one at a time. In the ostensive condition, a distinct function for each of the objects (i.e., a dial that, when turned, produced melody, and a handle that, when pulled, produced flashing lights) was ostensively demonstrated, as each emerged from behind the occluder, inducing infants to expect two objects behind the occluder at test. No such expectation emerged in the non-ostensive condition, when the potentially functional features of the objects were presented without ostension. These results suggest that ostensive function demonstration can have similar effects as labels in triggering kind-based representation. In the next sections I shall discuss the implications that accessing kind-based representations via nonverbal ostensive reference entail.

1.5 Learning about Kinds

An infant's world is populated by a multitude of objects: objects that they observe, engage with and are communicated about within their immediate environment by their caregivers. However, learning about the world is not restricted to learning about individual exemplars. Humans possess generic knowledge, which applies to whole categories, thus allowing to treat tokens of the same kind as equivalent in terms of their most relevant properties (Gelman, 2003). Humans can acquire generic knowledge in two ways: by interpreting generic expressions and by inductive generalization.

1.5.1 Generics

Generic statements are direct assertions of generic knowledge. They convey simplified and sweeping generalizations about kinds rather than about particular individuals, highlighting the attributes normatively shared by members of a category (Carlson, 1977). For example, the generic statement, ‘Solar panels generate electricity from sunlight’, is an assertion about all solar panels that have been made so far and will be made in the future. It is not about one or a few specific solar panels that might be in front of us while we produce this utterance, but about the entire kind symbolically represented by the noun phrase ‘solar panel’. Adults and even young children can easily and efficiently learn generic information from generic statements. Generic language does not have its own specific linguistic marker, and yet children are able to learn generic knowledge from generic statements already by 2.5 years of age (Graham, Nayer, & Gelman, 2011; Gelman & Raman, 2003). They understand that generic sentences are different from quantifier statements, like “some girls like pink”, and that generics are about kinds and not just about a random set of individuals (Brandone et al., 2012). They interpret information expressed in generic statements as conveying inherent and essential features of a biological category (Cimpian & Markman, 2009), or as expressing intentionally created functional properties of artefacts (Cimpian & Cadena, 2010). Recent evidence also suggests that generic statements can induce essentialist beliefs about novel social categories in both adults and children, and that having such beliefs in turns results in using generic statements to describe these social categories (Rhodes et al. 2012, 2017).

There are two key signatures that indicate that information has been appropriately assigned to a kind rather than to an individual:

1. *Resistance to counterevidence.* Generic statements express information about kinds, and not specifically about each member of the specified kind. This allows for tolerance to counterexamples (Leslie, 2007). For example, having learned that solar panels convert solar energy to electricity, coming across a defunct solar panel, or even hundreds of defunct solar panels, will not lead one to assume that solar panels as a kind cannot produce electricity. Despite counterexamples, our expectations from solar panels would be that they can produce electricity from sunlight. Generic knowledge acquired from generic statements is thus insensitive to confirming or disconfirming statistical information. Once generic knowledge about a kind is acquired, the kind is expected to possess the property, despite multiple exceptions (Prasada, 2000; Leslie et al., 2011, Cimpian et al., 2010).

2. *Shared knowledge.* Children interpret generic statements to be conveying stable, inherent and essential characteristics of a kind, rather than idiosyncratic characters of a kind that might be known only to the speaker (Cimpian & Cadena, 2010; Cimpian & Markman, 2009; Rhodes et al. 2012). When receiving information via generic statements, children assume that the information is widely shared knowledge about culturally relevant kinds. For instance, 4- to 7-year-olds were given novel facts either in generic (“Hedgehogs eat hexapods”) or non-generic (“This hedgehog eats hexapods”) statements. Children of both age groups held that others would be more likely to know the fact when it was stated generically than when it was stated non-generically (Cimpian & Scott, 2012).

1.5.2 Inductive Generalization

Inductive generalization is the process of learning about one or few exemplars of a kind and then generalizing the information learned about these examples to their kind. Upon learning that one object has a specific property, infants come to expect other objects of the same kind to exhibit this property, either by virtue of perceptual similarity or because these objects share the same label, which is readily interpreted to denote common kind even for perceptual dissimilar tokens. Several studies indicate that from before their first birthdays infants can engage in inductive generalizations (Baldwin, Markman, & Melartin, 1993; McDonough & Mandler, 1998; Vukatana et al., 2015). In a seminal study, Baldwin et al., (1993) demonstrated how to elicit a novel non-obvious property from a novel object to 9-16-month-olds. Subsequently, infants were handed over a test object that was either perceptually similar to or very dissimilar from the demonstration object. The test object was disabled, such that acting on it would not result in the demonstrated property being elicited. This allowed the experimenters to measure how perseverant the infants would be in attempting to elicit the property from the test objects, by counting the number of attempts infants engaged in. Baldwin and colleagues found that infants across age groups were more persistent on perceptually similar objects, indicating that they expected these to be more likely to exhibit the demonstrated property. These results suggest that infants generalized the observed property of the demonstration object to novel objects owing to their perceptual similarity. Several other studies employing the same paradigm confirmed that perceptual similarity is taken to license inductive generalizations about non-obvious object functions (Graham & Diesendruck, 2010; Graham & Kilbreath, 2007; Graham, Kilbreath & Welder, 2004; Welder & Graham 2001; Switzer & Graham, 2017). Furthermore, infants produced inductive generalization even in the presence of novel, but perceptually dissimilar objects which shared the same label as the

demonstration ones, thus indicating that they prioritize kind-relevant information over perceptual similarity for inductive purposes when the two are pitted against each other (e.g., Graham, Kilbreath & Welder, 2004; Welder & Graham 2001; Switzer & Graham, 2017; Keates & Graham, 2008).

It is conceivable that young infants may also acquire generic information by inductive generalization by abstracting out certain features as common to the kind. In such a case, infants are expected to evaluate how robust their inductive generalizations to kinds are on the backdrop of observed statistical prevalence (Rosch et al., 1976; Quinn & Eimas, 1996; Xu & Kushnir, 2013). There are two hurdles to acquiring generic knowledge this way: (1) statistical learning over multiple episodes would not only be a slow process, but it would also pose a *learnability problem* for how the properties thus observed can be evaluated to be a characteristic central feature of the kind (Csibra & Gergely, 2006). This is a particularly pressing issue that cannot be solved by adopting heuristics based on the feature prevalence, since this is a poor criterion to single out the fundamental kind properties of an object; (2) the process of arriving at generic knowledge about a kind can be derailed by counterexamples. These two problems – not knowing which information about an entity is a central defining characteristic of its kind, and encountering repeated counterevidence – pose serious challenges to the efficient acquisition of kind knowledge. These hurdles are particularly pronounced in preverbal infants because they, unlike linguistically proficient children, cannot capitalize on direct linguistic pathways to learning about kinds, such as comprehending generic utterances.

1.5.3 The Case for Nonverbal Generics

Csibra & Gergely (2006, 2009) proposed that ostensive referential communication induces infants to interpret information thus conveyed as kind relevant, thus allowing infants to directly interpret the information as generalizable to kind without having to rely on statistical prevalence. Several studies demonstrated that ostensive referential communication about novel objects can indeed bias infants towards interpreting the information expressed as non-episodic information relevant to the object kind (Butler & Tomasello, 2016; Okumura et al., 2016; Egyed, Király, & Gergely, 2013; Futó et al., 2010; Király, Csibra, & Gergely, 2013; Träuble & Bätz, 2014; Yoon, Johnson, & Csibra, 2008; Chen et al., 2011; 2012; Okumura et al., 2020). Furthermore, a key series of studies by Butler and colleagues (2012; 2014; 2016) further tested whether children would be especially prone to generalize information conveyed in ostensive referential contexts to other exemplars. In an study with preschool children and 24-month-olds (Butler & Tomasello, 2016), the experimenter introduced a novel object and

taught the children its name ‘blicket’. The children were then shown that blickets are magnetic in pedagogical, accidental, or intentional condition. They were then given a set of non-magnetic blickets and were told “here are some blickets, go ahead and play”. When given the opportunity to explore the new blickets, children in the accidental and intentional condition abandoned their attempts after trying a few inert blickets, whereas children in the pedagogical condition continued to persist in their attempts to elicit the property from the blickets. These studies suggest that while information acquired from non-ostensive contexts is vulnerable to counter-evidence (as inductively inferred information is expected to be), information ostensibly demonstrated shows a resilience to counter-evidence.

Importantly, other studies similarly showed that ostensibly communicated information may be interpreted by children in the same way as generic statements. Recall that information acquired via generics statements require scant evidence, yet are taken to refer to inherent, characteristic, enduring properties (Cimpian & Cadena, 2010; Rhodes et al., 2012). A study utilizing the same paradigm as Butler & Markman (2012), but with older children, showed that information conveyed within ostensive referential contexts was interpreted as being about defining characteristics of the kind, similar to information conveyed through verbal generics (Butler & Markman, 2014). In this study, five-year-olds were introduced to a novel object and taught that the object was named ‘spoodle’. The children were then demonstrated that spoodles are magnetic in a pedagogical, accidental, or intentional condition. They were then handed over a set of 16 objects, 8 of which were identical in shape to the demonstration objects and 8 different. Four objects in the shape-similar and 4 in the dissimilar set were magnetic. The children were told by the experimenter that “some of these are spoodles and some of these are not spoodles” and were instructed to put the spoodles in one box and the non-spoodles in another. Children who had received the ostensive demonstration categorized the objects as being of the same kind as the demonstration object, if the objects possessed the property, ignoring shape information. Children in the non-ostensive condition, on the other hand, categorized the objects on the basis of shape, sorting objects that had the same shape as the demonstration objects as spoodles, thus disregarding their magnetic property (or lack thereof).

Building on these findings, which suggest that information conveyed in ostensive contexts are not simply imbued with stronger inductive potential but instead show signatures of being encoded as generic as information from generic statements are, Csibra & Shamsuddeen (2015) proposed that nonverbal ostensive referential communication can function as nonverbal generics. Crucially, this proposal provides an avenue for preverbal

infants to acquire generic knowledge just as older children do – i.e., from ostensive demonstrators and in one-shot communicative encounters by passing inductive generalisation.

One important caveat for our proposal is that, ostensive deictic reference to an object is directed at a specific exemplar in the physical space and thus directly linked to it, unlike verbal generic labels that have a more abstract reference to kinds, and can be presented delinked from any specific exemplar (Edmiston, & Lupyan, 2015). As a consequence, if nonverbal ostensively communicated information about specific exemplars are to be interpreted as generic information, the referent object that is at the focus of ostensive reference must receive a kind-based representation or in other words, act as deferred indexicals that refer to the kind it exemplifies. In adults it is possible that task demands alone can trigger kind-based representations of objects, allowing them to deal with both familiar and novel objects as symbols that represent their kinds. What may conceivably allow adults to spontaneously form kind-based representations for objects seems to be an existing notion of ‘kind,’ which would entail that any and all objects belong to some kind, with members sharing non-obvious essences that define their kind membership and style their evident features (Gelman, 2003). However, influential studies indicate that young infants do not spontaneously form kind-based representations of objects without verbal prompts (Xu, 2002). These results led to conclude that infants may be unable to represent in terms of kind until they have acquired generic labels that can directly refer to kinds. The verbal labels are proposed to stand in as ‘essence placeholders’ that can come to carry generic information about kinds. Generic phrases-kind labels, like generic statements, license kind representations even when their immediate referent consists of a particular, spatiotemporally defined object. Being able to tap into the notion of kind and encode any object in reference to its kind is a basic requirement for mapping information about an object to its kind. When generic language is used, such notion of kind can be immediately made apparent via the linguistic format. In contrast, to interpret expressions as nonverbal generics, one would need to spontaneously encode an object as representing its kind, thus going beyond the attentional spotlight shone on the spatiotemporally marked entity referred to via deictic referential gestures. In the present thesis we will primarily focus on how this criterion for kind representation through nonverbal generics is fulfilled.

1.6 Summary and Hypotheses

Our direct experiences with objects are always limited to particular exemplars, as kinds cannot be presented physically. Even if an object happens to be the sole member of a kind,

the object in its physical reality exists as a specific entity. It is thus puzzling that, despite that we always encounter and learn about particular objects, our knowledge of these objects encompasses the categorical scope their kinds belong to, rather than being restricted to the specific objects themselves. This puzzle of how information conveyed in episodic instances about particular objects is generalized to their kind category is referred to as the *problem of induction* (Markman, 1989). Several theories of concept formation have tried to solve the induction problem by proposing that knowledge about kind is acquired through statistical learning over multiple episodes (Rosch et al., 1976; Quinn & Eimas, 1996; Smith et al., 2002; Xu and Kushnir, 2013). However, Statistical learning over multiple episodes, as we already argued, is a slow and error-prone process, which poses a *learnability problem* for how the kind-relevance of any piece of information can be judged (Csibra & Gergely, 2006).

These issues can be resolved when learners rely on knowledgeable others to guide their learning process (Gelman 2009; Harris, 2002; Leslie, 2007). This guidance consists in making linguistically which properties are kind-relevant and thus generalizable (Gelman et al., 2004). Exploiting such forms of linguistic inputs is obviously beyond the grasp of preverbal infants. How then do infants learn that communication can be about a kind and not about the particular object being referred to in a communicative interaction? Gergely & Csibra (2006) proposed the theory of Natural Pedagogy, which states that ostensive communication plays a crucial role in conveying opaque, novel and kind-relevant information. We already discussed studies showing that infants can identify and attend to nonverbal communication due to their evolved sensitivity to ostensive signals such as eye contact, contingent reactivity, or infant-directed speech (Csibra, 2010). Such ostensive signals trigger the expectation that the communicator is showing to the learner information that is both kind-relevant and socially shared (Gergely & Csibra, 2013; Csibra & Gergely, 2009). Compatibly with this claim, preverbal infants interpret information learned in ostensive referential contexts to go beyond the episodic attentional ventures of individual communicative episodes (Butler & Tomasello, 2016; Okumura et al., 2016; Egyed, Király, & Gergely, 2013; Futó et al., 2010; Király, Csibra, & Gergely, 2013; Träuble & Bätz, 2014; Yoon, Johnson, & Csibra, 2008; Chen et al., 2011; 2012; Okumura et al., 2020). Further studies probing the interpretation and encoding of information presented within ostensive contexts showed that information thus conveyed exhibits signature properties of information conveyed through verbal generics, such as resistance to counter evidence (Butler & Markman 2012; 2014; Hernik & Csibra, 2015; Butler & Tomasello, 2016), and a propensity to take the information thus acquired as defining central characteristics of the kind (Butler & Markman, 2014), to be privileged over statistical information (Marno & Csibra, 2015).

Taken together, this literature points at three key findings suggesting that young infants without sophisticated linguistics skills may acquire generic knowledge from nonverbal ostensive referential communication. Young infants: (1) have an early-emerging sensitivity to ostensive signals, which indicate that they are being communicated to; (2) can readily learn to recognize referential signals such as pointing; and (3) are biased to interpret information conveyed via ostensive referential acts as relevant to the kind. Given these early competencies in interpreting ostensive communication, Csibra and I proposed that infants should be capable of interpreting nonverbal ostensive communication as conveying kind information even before mastering verbal generics (Shamsudheen & Csibra, 2015). Under this account, learning about kinds via nonverbal generics would not hinge on inductive generalization as it has been previously proposed (Butler & Markman, 2012; Gelman, 2003; Markman, 1989). Instead, ostensive referential communication is taken to directly induce the expectation that the object being communicated about symbolically represents its corresponding kind, thus resolving the induction puzzle of how we manage to learn about kinds despite only encountering spatiotemporally isolated instances of it. (Prasada, 2000).

Our proposal for nonverbal generics asserts that nonverbal demonstratives produced in ostensive contexts automatically evoke kind-based representations. We investigate the premise that young preverbal learners are inclined to utilize nonverbal and ostensively communicated information to learn about kinds rather than particulars, much like how language users use verbal generics. Primarily, this thesis attempts to answer the question of whether ostensive communication triggers kind-based representations of the referred targets. This proposal yields four behaviorally observable hypotheses:

- (1) The target of ostensive referential communication embodies its kind. Despite that kinds cannot be physically instantiated, but we can still conceive of kinds by representing an object 'x' as representing 'K', its kind. Past research shows that at 9-months of age infants are unable to spontaneously perceive even familiar objects as tokens of their kinds unless these are labeled with their count nouns (Xu, 2002). We propose that if ostensive reference can trigger kind-based representation, infants should succeed at tasks that require kind-based representations, when the objects are presented in episodes of convergent ostensive communication and referential acts such as pointing. This hypothesis will be explored in Chapter 2.

(2) Having formed a kind based-representation, infants should interpret information conveyed about an ostensively referenced target as generic. This hypothesis will be examined in Chapters 3 and 4.

(3) A consequence of interpreting the information as generic is resistance to counterevidence. If nonverbal generics spontaneously trigger kind-based representations, such a resistance should be observed even with single-shot learning episodes, without having had the opportunity to generalize over multiple exemplars. Under our proposal, generic information thus conveyed should be acquired in one-shot and fast-mapped to the kind, just as older children do upon acquiring verbal generics. This hypothesis will be investigated in Chapter 3.

(4) Despite enhanced attention to the particular object being referred to, infants should not assign a differential status to the this specific object, for instance, by designating it as the 'best' or most representative example of the kind, but expect other objects of this kind to similarly exhibit the demonstrated kind-relevant property, even despite receiving negative evidence from other exemplars of the same kind. This hypothesis will be put to test in Chapter 3.

1.7 Overview of the Thesis

In **Chapter 2** I will present and discuss evidence that ostensive reference is sufficient to induce a kind-based representation from familiar objects kinds. Using an individuation paradigm modelled after Xu & Carey (1996), 9-month-olds were familiarized with two different objects from two familiar kinds that emerged one at a time from behind a screen, such that the infants never saw the two objects simultaneously. As each object was brought out from behind the occluder, they were ostensively referred to. This presentation sufficed to make infants individuate two objects behind the occluder at test (Experiment 1). However, when the objects featured as exemplars of the same familiar kind, infants failed to individuate the two objects during test, despite the ostensive presentation (Experiment 2). These results confirmed our hypothesis that ostensive referential communication can trigger kind-based object representation of familiar objects kinds.

In **Chapter 3** I will report a study explicitly designed to test the propensity of 18-month-olds to extend a novel property demonstrated ostensively or non-ostensively on a single exemplar to other objects of the same kind. Subsequent to the demonstration, infants

were given two inert objects to explore. Persistence in eliciting the demonstrated property from these inert exemplars was measured. Infants who received the ostensive demonstration persisted longer in eliciting the demonstrated property from a second inert object, despite having already experienced failure from a first inert object. This result supported our hypothesis that information conveyed in ostensive referential contexts is fast-mapped to the kind as generic knowledge about the kind, resulting in resistance to counter evidence. However, this effect was observed only when the three objects were labelled with a common name (Experiments 2 & 4). Adding to this, we further ascertained if labels helped infants to identify novel exemplars as kind members from which the generic knowledge acquired via nonverbal generics can be expected (Experiment 3).

Finally, **Chapter 4** reports a set of studies designed to test whether the ostensive referential nature of labelling predisposes labels to be mapped as kind nouns even when a single exemplar of a kind is labelled. We found that only when an unfamiliar object was ostensively referred to the subsequent label was ascribed to it. When the object was highlighted with non-ostensive non-referential, but nevertheless intentional, the label failed to be properly mapped to the object. These results are compatible with our hypothesis that ostensive reference induces the formation of a kind-based representation for unfamiliar objects, and opens a kind placeholder that subsequently expressed predicates can be mapped onto.

Chapter 2

**Nonverbal reference facilitates
object individuation**

2.1 Introduction

During our daily lives when we interact with objects, we utilize our ability to recognize that these objects are kind members and have kind characteristics. For instance, when interacting with novel instances of familiar kinds, such as when we board a bus, use cutlery, roast chestnuts, or switch on a TV, we make use of our knowledge about these object kinds. This is only possible if we are able to encode and represent an entity 'X' as representing its kind 'K'.

2.1.1 Kind-based Object Individuation

There is no reason to doubt that adults are fully capable of forming kind-based representations spontaneously, without any specific prompts such as labels. In fact, evidence from some influential studies show that, by 12-months of age, infants spontaneously form kind-based representations of familiar objects (Xu & Carey, 1996; Xu, Carey, & Welch, 1999; Walle, Carey, & Prevor, 2000; Xu, Carey, & Quint, 2004). On the other hand, these studies reported the rather curious phenomenon that younger infants, unlike 12-month-olds, being unable to do the same. For instance, an influential study by Xu and Carey (1996) utilized an individuation paradigm that allowed them to test how many objects infants represented in a given event. They exposed infants to a familiarization phase, in which infants observed two objects of different kinds (e.g., a ball and a cup) emerge one at a time from behind an occluder, such that each of the object was visible to the infant only while the other was behind the occluder. After the familiarization phase, at test the occluder was removed to reveal either a two-object outcome or a single-object outcome. When presented with the single-object outcome, 12-month-olds looked longer than to the double-object outcome, indicating a violation of their expectation for two objects. Xu and Carey (1996) found that among the infants tested, only the 12-month-olds, but not the 10-month-olds developed an expectation that there must be two objects involved in the event. That is, the 10-month-olds failed to infer from the presence of two distinct kinds that two distinct objects were present in the event.

Follow-up studies demonstrated that the success of 12-month-olds and the failure of 10-month-olds at this task stemmed from the 12-month-olds, but not the 10-month-olds, being able to spontaneously encode the objects in terms of their kind. Xu, Carey, & Quint (2004) demonstrated that 12-month-olds fail on the task when the objects involved in the event are of the same kind and differed only on visual features such as color, size, or a combination of color, size, and visual pattern. Crucially, indicating that they are individuating based on forming distinct kind representations, and not on more striking visual features such

as shape, they succeed only when the objects are of different kinds, and fail on the task even if the objects differ in shape but are of the same kind (such as a regular cup and a sippy cup).

In contrast to the success of 12-month-olds, who spontaneously form kind-based representation of familiar objects, 10-month-olds fail in this task (but see Rivera & Zawaydeh, 2007). However, further research revealed that 10-month-olds and even 9-month-olds can succeed at these tasks if they are given prompts that facilitate forming kind-based representations. In a paradigm that was near identical to the Xu and Carey (1996) study, except that each object was labeled with a count noun as it emerged from behind the screen, 9-month-olds looked longer at the single-object outcome, indicating that they expected two objects (Xu, 2002). When, instead of two distinct count nouns (indicating two kinds), a single word ‘toy’ was used for both objects, or when two contrastive emotive sounds were used for the two objects, infants did not show an expectation for a two-object outcome. This led to the proposal that, since count nouns map onto kinds, two distinct labels aid the infant in forming two distinct kind-based representations (Xu, 2002; 2007). Acquiring count nouns has been suggested to play a causal role in infants’ acquisition of basic level kind concepts. Before achieving this, infants were proposed to only hold general representations of ‘objects,’ which are separated and tracked spatiotemporally. This representation is not based on the kind the object belongs to, such as ‘ball’ or ‘shoe’ (Xu & Carey, 1996; Xu, 2012). Other researchers have meanwhile reported that infants younger than 12 months of age can individuate and represent objects in terms of their more abstract global categories, such as ‘human’ and ‘agent’ even without linguistic support (Bonatti et al., 2002; Surian & Caldi, 2010).

In contrast to the claims that, for infants below one year of age, naming is unique in facilitating the encoding of an object in terms of its kind by acting as an ‘essence placeholder’ for the kind (Xu, 2005, 2007), others proposed that functional information can also play this role. Futo and colleagues (2010) utilized Xu and Carey’s (1996) individuation paradigm to probe whether 10-month-old infants would capitalize on functional information to individuate two novel objects. In the familiarization trials, the infants were introduced to two novel objects that were brought out one at a time from behind an occluder by an experimenter who addressed them in infant-directed speech. The experimenter then demonstrated an instrumental action on the object that led to the object manifesting a novel property. The object was then placed back behind the occluder and the other object was brought out from the other side of the occluder. An instrumental action, distinct from the one performed on the first object, was demonstrated on this second one, resulting in the object manifesting a property different from that of the first one. In effect, the infants were presented with two objects, on which two different instrumental actions were performed that led to two different

outcomes. Given that infants of this age do not use features to individuate objects, the question was whether 10-month-old infants would be able to utilize these function demonstrations as information indicating two distinct kinds of objects behind the occluder. Results from the study revealed that infants looked longer when the occluder was lifted and a single object was revealed, indicating that the infants had bound the demonstrated properties to object kinds and that they must have assumed that two different functions indicated two different kinds of objects (just as two different labels allow for the expectation of two different kinds). This result was interpreted as an indication that ostensively demonstrated function is a kind relevant property that can aid 10-month-old infants in forming kind-based representations. However, there is a common element in a labeling act and an ostensive functional demonstration: Both of these are ostensive referential communication, which I have proposed can trigger kind-based representations (Csibra & Shamsuddeen, 2015). Thus, an important question is whether a non-ostensive function demonstration can also induce kind-based encoding of the objects.

The non-ostensive condition that Futo et al. (2010) ran answers this question. In this condition, they presented the same action-outcome information about the objects to the infants but this time the instrumental actions were presented without ostensive signals. In this condition, 10-month-old infants failed at the individuation task. In this condition, the objects had different perceptual features, different instrumental actions were performed on them, which even produced different outcomes. But, just like the 10-month-old infants in Xu and Carey's original experiment (1996), here the 10-month-olds failed to utilize any of these differences between the objects to individualize them. It was only when the infants were given an ostensive demonstration of the distinct functions that the infants were able to form kind-based representations and individuate the objects.

In a third condition, Futo and colleagues presented infants with the very same object twice, but each time they demonstrated a different action on it that led to a distinct outcome. If the infants attended to individual features of the object, they could have noticed that it was the very same object brought out from either side, and although the object displayed two functions, they should have expected a single object behind the occluder. However, when the occluder was lifted to reveal a single object, the infants looked longer, indicating an expectation of two objects. Evidently, despite the very same object being presented to them twice, infants seemed to have formed the expectation of two kinds, assuming that the two functional demonstrations indicated two mutually exclusive kinds of objects. Since 10-month-old infants individuate by kind and not by features, we can interpret this result as indicating that infants were definitely binding the demonstrated action-outcomes as kind relevant functions, and not as features, to distinct individual objects – but only when the function was demonstrated in an

ostensive-referential context. The important point to be noted here is that, when infants saw two distinct objects that had two distinct functions, they did not encode them as two different kinds, but ostensive demonstration of two distinct functions on even the very same object led them create two separate kinds. This suggests that neither distinct features of the object, nor distinct functional properties are interpreted as kind relevant information without ostensive reference.

2.1.2 The Current Study

Previous research shows that:

- 1) Infants before 12-months of age do not succeed at utilizing featural information on Xu and Carey's (1996) individuation task;
- 2) Infants younger than 12 months do not spontaneously form kind-based representations;
- 3) Ostensive communication of kind-defining properties such as count-nouns and function can induce kind-based representation of objects.

We have proposed that ostensive reference triggers a kind-based representation of objects (Csibra & Shamsudheen, 2015), which would in turn allow for any information that is delivered in such contexts to be bound to kind (Chapter 1). This proposal allows us to hypothesize that, for successful individuation of familiar objects on the Xu and Carey's (1996) individuation task, ostensive reference alone, without the explication of any further predicates, such as labels or functions, should be sufficient even for younger infants. This follows from the assumption that familiarity with objects makes infants capable of forming kind-based representations of them, and so ostensive reference on familiar should trigger such encoding even in the absence of further information. If 9-month-olds are capable of kind-based object individuation, forming such representations should then allow them to individuate objects.

In the current study, we investigated whether 9-month-olds can individuate familiar objects given only nonverbal ostensive reference. The experiment followed the object individuation paradigm developed by Xu & Carey (1996) with a few modifications to include ostensive reference to the objects. The infants were tested using pre-recorded video clips presented on a large TV screen. The infants were familiarized to the experimental set-up before the experiment proper began. During the familiarization, a voice addressed the infants with their name in infant directed speech. Two objects, a shoe and a ball were used in the experiment. They were brought out by a hand one at a time from behind an occluder, such that they were never seen together. Crucially, when the objects were visible, the hand pointed to them, and infants-directed speech made it evident that this referential action was addressed

to the participants. At the test, the occluder was removed to reveal either a single-object outcome or a double-object outcome, and the infants' looking time was measured. If ostensive referencing can trigger an object to be represented in terms of its kind by the virtue of being communicated about, then the infants would be able form a kind-based representation for the two objects, and hence would expect two objects to be present behind the occluder. We predicted that the single-object outcome will violate this expectation and hence they will look longer at that outcome compared to the double-object outcome.

In subsequent experiments using a similar design we addressed the questions whether ostensive reference via deictic gestures would simply highlight object features (Experiment 2), and whether nonverbal reference and labeling produce comparable kind representations (Experiment 3 & 4).

2.2 Experiment 1. Ostensive Pointing to Familiar Objects of Different Kinds

We ran an individuation task modeled after Xu and Carey (1996) with a few modifications to include ostensive reference to the objects as they emerged from behind the occluder. The infants were presented with pre-recorded video clips, in which two familiar objects (ball and shoe) were brought out one at a time from behind an occluder and then was held up and pointed to before being put back behind the occluder. The clips were accompanied with a live voice-over, with the infants being addressed in infant-directed speech and by their own name. Using pre-recorded video clips allowed us to ensure standardized presentation of the objects and action sequences to the infants, while the live audio provided an infant-linked ostensive context.

2.2.1 Methods

2.2.1.1 Participants

Sixteen 9-month-old (mean age 9 months 5 days, age range: 8 months 15 days - 9 months 15 days) full-term, healthy infants from native Hungarian speaking families were included in the final sample. Six additional infants participated but were excluded because of looking away and missing crucial parts of the events (4 infants) or fussiness (2 infants). Informed consent was obtained from the parents before the experiment began.

2.2.1.2 Apparatus and Stimuli

The experiments were run in a dimly lit, soundproof testing room, with an adjoining control area from where the experiment was administered. A camera placed above the screen recorded the infant, and also transmitted to a computer screen in the control area. The visual stimuli consisted of video clips pre-edited with Final Cut Express 4.0, presented using Keynote software 5.0 on a 90 cm * 50 cm LCD screen. The video clips were accompanied by live, infant directed speech and occasional short musical jingles, transmitted to the infant over speakers. The speech was pre-scripted, and all infants received the same verbal input (except their names) and musical jingles at identical time points during the experiment.

Four different objects were used in the videos. Two objects, a blue hand-held massager and a red stapler were expected to be novel and unfamiliar for 9-month-old infants and were used in the familiarization and baseline trials. Two objects from categories reported to be familiar known kinds for the majority of 9-month-old Hungarian infants (Parise & Csibra, 2012) were used in the test trials: a shoe (a red infant shoe of lace-up bootie style) and a yellow tennis ball. An orange screen (28 cm wide, 30 cm high) was used as the occluder in all trials.

2.2.1.3 Procedure

Prior to entering the testing room, parents were greeted by an experimenter and given a short briefing about the general nature of the experiment. They were explained that the experiment involved the infant's behavior being video recorded while they watched a series of videos displaying various objects being moved around by a hand on a table. Parents were requested to remain silent and to not influence, interact or interfere with the infant's behavior during the experiment. They were also requested to close their eyes when instructed by a written reminder displayed on the screen, and to keep them closed for the remaining duration of the experiment.

The experimenter then accompanied the parent and the infant into the testing room, and seated the parent on a chair placed 100 cm away from the presentation screen. After the infants were seated on their parent's lap and oriented towards the screen, the experimenter stepped out of the testing room into the control area, from where she could speak to the infant through a microphone. The entire experiment was video recorded for offline coding of infants' looking behavior.

The experiment began with a familiarization trial, followed by two baseline trials, followed by another familiarization trial and then two test trials. An animated attention getting stimulus accompanied by a short musical jingle was played between consecutive trials. At the end of the experiment, the recorded video of the infant was played back to the parents, while

they were given a brief description of the research question and how it was addressed by the experiment.

Familiarization Trials. The familiarization trials were intended to introduce the infants to the general testing conditions, and the various action events that would occur during the baseline and test trials, such as the experimenter speaking to the infant at various time points, the musical jingles that were played, that there could be objects present behind the occluder and that the occluder could fly up and move out of the display without affecting the objects.

The familiarization videos began with the orange occluder positioned in the middle of a light grey table against a black background while the experimenter spoke to the child over the microphone in infant directed speech, “Szia, [infant’s name]” (“Hi, [infants’ name]”) (1.10 s). Following the greeting, the experimenter said “Figyelj!” (“Watch!”) as a hand moved into the video display from one of the sides (left or right), slid across the table and pulled out one of the familiarization objects from behind the occluder. The hand dragged the object across the table until it was 11 cm from the edge of the occluder (4.14 s) while a short musical jingle was played. The hand then held the object up and displayed the object by turning it to either side and downwards, while the experimenter said “Nézd csak! Látod?” (“Look! See?”) in infant-directed intonation (6.7 s). The object was then placed on the table, 11 cm away from the edge of the occluder. The hand then skimmed out of the video display at the same side it had emerged from, accompanied by another musical note (1.16 s). Once the music ended, and the hand was completely out of the display, the experimenter said “Ezt nézd!” (“Look at that!”) while the occluder and object remained still (2.5 s). Immediately following this, a hand emerged into the display from the other side. The same procedure as with the first object, with identical speech and jingles at corresponding events, was now repeated with the second familiarization object. The hand brought out an object, held it up, displayed it and then placed the object 11 cm away from edge of the occluder, and then skimmed out of the video display. Once the hand was out of view, the experimenter said “Ezt nézd!” (“Look at that!”) as earlier, and a still display with the two familiarization objects on either side of a static occluder was displayed (3 s). Finally, the occluder flew up and out of the display (2 s), leaving the two objects standing on the table. After 2 seconds of still display, the familiarization trial ended. The presentation order of the objects and the side from which the objects were presented was counterbalanced across infants but kept constant across the two familiarization trials for each infant.

After the familiarization trial ended and 2 seconds of the attention getter was presented, or when the infant had oriented back to the display if they had looked away, the baseline trials began.

Baseline Trials. The baseline trials were meant to measure whether infants would show an inherent tendency to look longer at a single-object display than a double-object display when two distinct objects are presented simultaneously side by side in the absence of any prior expectations on how many objects they would see when the occluder went up. Hence, the baseline trials did not involve any prior actions or occlusion events before the occluder went up to reveal either a single-object or double-object outcome. Since the experiment hinged on the idea that infants would gaze longer at a single object when they detect a violation of their expectation of two objects, it was important to ascertain if there was any pre-existing tendency to look longer when a single object was presented by itself.

The baseline trial videos began with the occluder positioned in the middle of a light grey table against a black background (2.8 s), during which the experimenter addressed the infant over the microphone in infant directed speech (“Figyelj!”) (“Watch!”). The occluder lifted up and moved out of the display (2 s), revealing either one of the objects used in the familiarization trial (single-object outcome) or both of them (double-object outcome). Infants’ looking time was measured from the point in time when the occluder was fully out of the display. The trial was terminated when the infant had looked away for 2 consecutive seconds or 60 s had elapsed since beginning of measurement.

The second baseline trial started after an attention getting stimulus was displayed to reorient the infant back to the display. The second baseline trial was identical to the first one except in the number of objects (1 or 2) the occluder moved away to reveal. The order of the outcome (single-object outcome first or double-object outcome first), which object was presented in the single object display (stapler or massager), and the side (left, right) each of the objects occupied relative to each other in the double-object display were counterbalanced across infants.

After the two baseline trials, a second familiarization trial was presented, identical to the first familiarization trial. The test trials commenced after the second familiarization trial was presented.

Test trials. The test trials began with the occluder positioned in the middle of a light grey table against a black background (Figure 2.1) while the experimenter spoke to the child over the microphone in infant-directed speech (“Figyelj, [infant’s name]”) (“Watch, [infants’ name]”). Just as the greeting ended, a hand moved into the display from one of the lateral sides, accompanied by a second “Figyelj!” (“Watch!”). The hand slid across the table and pulled

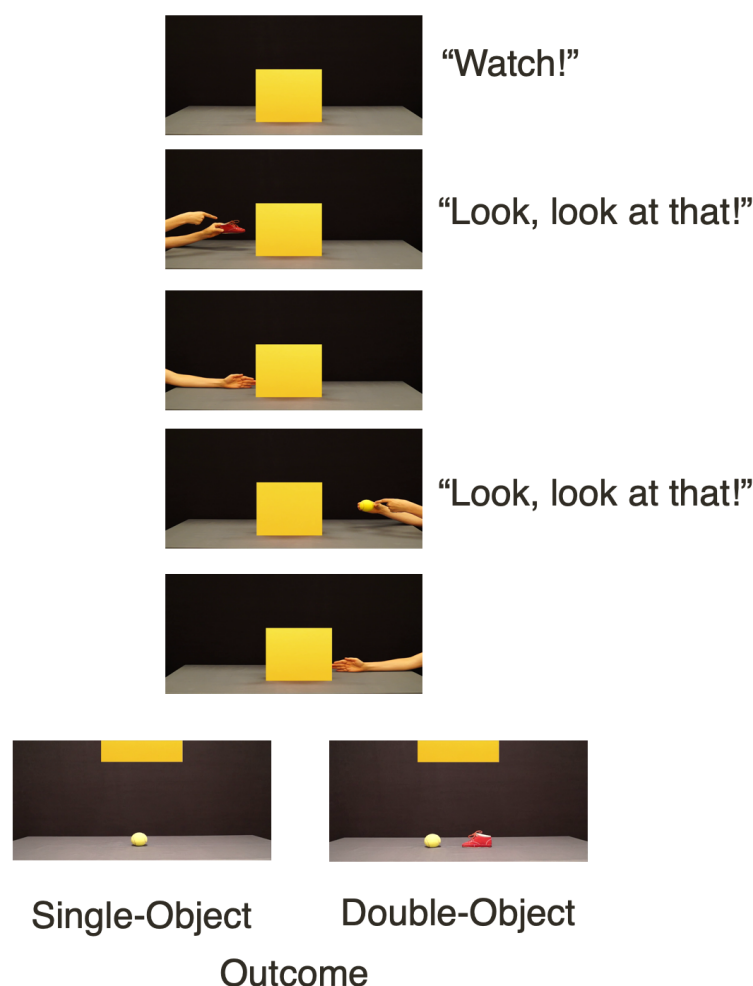


Figure 2.1. Schematic illustration of the procedure in the test trials of Experiment 1.

out one of the familiar objects from behind the occluder, until it was 11 cm away from the edge of the occluder (6.0 s). The emergence of the object from behind the occluder was accompanied by a short musical jingle. The object was then lifted from the table and held up, while a second hand came into view from the same side. This hand pointed at the object while the experimenter said “Nézd! See?”, and then the pointing hand went back out of the display area and the object was lowered back onto the table (6.5 s). The hand then moved out of the display area, leaving a static image of the occluder and the object beside it, while the experimenter said “Ezt nézd! Látod?” (“Look at that! See?”) (3.0 s). The hand then slid back into the display area, slid across the table and dragged the object along the table to place it behind the occluder again, accompanied by a short musical jingle, then re-emerged without the object and slid back out of the display scene (7.0 s).

After 3.5 s pause, during which only the occluder was visible, another hand emerged from the other side of the display area, slid across the table to move in behind the occluder and bring out the second familiar object, while the experimenter said “Figyelj!” (“Watch!”).

The same action sequence that was carried out with the first object on the other side of the occluder was repeated on the second familiar object with identical speech and jingles. Once the hand replaced the object behind the occluder and slid out of view, leaving a static occluder in view (3.5 s), the occluder lifted up and moved out of the display area (2.0 s), revealing either one or the other object (single-object outcome) or both of them (double-object outcome). Infants' looking time was measured beginning from the point in time when the occluder was fully out of the display. The trial was terminated when the infant had looked away for 2 consecutive seconds or 60 s had elapsed since beginning of measurement.

The second test trial began after an attention getting stimulus was displayed to reorient the infant back to the display. The second test trial differed from the first test trial only in the outcome (single object or two objects) that the occluder revealed. The side from which the objects were presented (left or right), the presentation order of the objects (shoe first or ball first), and the order of outcomes (single-object outcome first or double-object outcome first), and which object was presented in the single-object outcome, was counterbalanced across infants.

2.2.1.4 Dependent Measure and Coding

During the experiment, look-away durations were determined online by the experimenter. The looking behavior of the infants was also coded offline, frame-by-frame on the recorded videos.

Only infants who attended to all the dynamic change events (bringing out the object from behind the occluder, non-verbal reference to the objects, placing the object back behind the occluder, ascent of the occluder revealing the outcome) during the experiment were included in the final analysis. Four infants were excluded because failed to meet these criteria.

2.2.2 Results

Preliminary analyses did not show any effect of presentation order, the object presented in the single-object outcome, or presentation sides of the objects. Further analyses were thus collapsed over these variables. All analyses reported are performed on log-transformed looking time data (Csibra, Hernik, Mascaro, Tatone, & Lengyel, 2016), but we report untransformed data in the text and in the figures.

Looking times were analyzed with a 2 X 2 repeated-measures ANOVA with trial type (baseline vs. test) and outcome (single-object vs. double-object) as factors (Figure 2.2). No significant main effects were revealed, but significant interaction was observed between trial type and outcome, $F(1,15) = 10.662$, $p = .005$, $\eta_p^2 = .385$. Planned paired t-tests revealed that

the interaction was due to infants looking significantly longer at the single-object outcome ($M = 8.7$ s, $SD = 5.5$ s) compared to double object outcome ($M = 5.2$ s, $SD = 3.0$ s) during the test trials ($t(15) = 3.109, p = .007, d = 0.777$). No significant difference was revealed at baseline trials ($t(15) = 1.037, p = .316, d = 0.259$), with similar look duration to the single-object outcome ($M = 9.3$ s, $SD = 5.9$ s) and to the double-object outcome ($M = 10.3$ s, $SD = 5.1$ s).

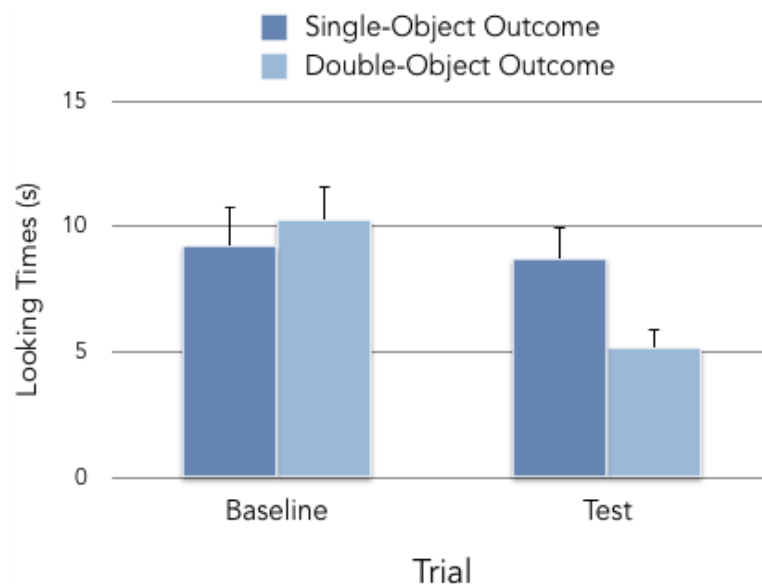


Figure 2.2. Looking times in Experiment 1 as a function of trial and outcome. Error bars depict standard error of the means.

2.2.3 Discussion

The results show that our participants formed an expectation that two objects were involved in the event. They arrived at this expectation even without verbal labeling of the objects, demonstrating that ostensive reference alone without any further kind defining attributes being presented was sufficient in promoting kind-based representations of the familiar objects. Previous research has shown that, although infants this age and younger can encode kind irrelevant features of objects (Wilcox, 1999; Wilcox & Baillargeon, 1998), they are unsuccessful at using them to individuate between objects on in the standard individuation paradigm (Xu, Carey, & Quint, 2004). Thus, infants' success at individuation in this experiment can be assumed to be kind based and offers direct support to our proposal that non-verbal ostensive reference can trigger kind-based representations. In this case, since the objects were from distinct familiar kinds, kind representations led to the successful individuation of the objects. Previous research has indicated that, when words are shorn of their ostensive referential packaging, they no longer facilitate categorization and inductive generalization

(Fulkerson, Shull, & Haaf, 2002; Campbell & Namy, 2003; Keates & Graham, 2008). Given the results we report here, it is plausible to suspect that words are linked to kinds by virtue of labeling acts being presented as ostensive referential acts, which induces a kind based representation of the labeled object, allowing the label to be linked to its kind (a hypothesis that we tested in the study presented in Chapter 4).

Our results are further supported by proposals according to which ostensive reference can trigger the activation of the generic semantic knowledge system that subserves kind based knowledge (Hoehl et al., 2014). In contrast, others proposed that ostensive contexts generally enhance attention towards the target object (Szufnarowska et al., 2014; Gredebäck, Astor, & Fawcett, 2018). This proposal would suggest that ostensive reference simply enhances attention to the target objects, which allows infants to encode the idiosyncratic features of the objects better, thus allowing for successful feature-based object individuation. Experiment 2 tested this proposal.

2.3 Experiment 2: Ostensive Pointing to Familiar Objects of the Same Kind

In Experiment 1 we found that nonverbal ostensive referential communication was sufficient to facilitate individuation of two exemplars from two distinct familiar categories at 9 months of age. However, this facilitatory effect could have been due to either enhanced attention to the distinct idiosyncratic visual features of the two objects or kind-based representation of them. Holding up the objects and pointing to each of them could have resulted in an attention enhancing, spotlight-like effect to the idiosyncratic and dissimilar, but kind-irrelevant features, allowing the 9-month-olds to represent them as separate objects and thus individuate them. Alternatively, non-verbal ostensive referential communication could have triggered a kind-based encoding, activating the representation of the objects as members of two distinct familiar kinds, thus allowing the infants to individuate the two objects.

Experiment 2 aimed to determine which of these factors could have been at work in Experiment 1. If the successful individuation in Experiment 1 was the result of enhanced attention to the dissimilar physical features of the two objects, then 9-month-olds should be able to successfully individuate two objects that display different visual features but belong to the same kind. Experiment 2 tested this prediction by pitting each of the test objects used in Experiment 1 against exemplars that shared kind membership with them but displayed different visual features, such as size, color, and texture.

2.3.1 Methods

2.3.1.1 Participants

Sixteen 9-month-old (mean age = 9 months 3 days, age range: 8 months 15 days – 9 months 15 day) full term, healthy infants from native Hungarian speaking families were included in the final sample. 8 additional infants participated but were excluded due to looking away and missing critical events (4 infants), fussiness (3 infants), and experimental error or technical errors (1 infant). Informed consent was obtained from the parents before the study began.

2.3.1.2 Apparatus and Stimuli

The same experimental set up used in Experiment 1 was used. The familiarization and baseline trials used the same stimuli as in Experiment 1. For the test trials, each of the object used in Experiment 1 was paired their respective kind members, forming two pairs of within-kind test stimuli, each pair from different familiar categories. The red shoe used in Experiment 1 was paired with a fluorescent green- and pink-patterned open-toe sandal-style infant shoe, and the yellow tennis ball from Experiment 1 was paired with a multicolored satin-textured stuffed Ikea ball. The same occluder as in Experiment 1 was used in all trials.

2.3.1.3 Procedure

The same procedure as in Experiment 1 was followed. Familiarization and baseline trials were also identical to Experiment 1. Only the test trials were different from those of Experiment 1. Each infant received one test trial with one pair of objects and the second test trial with the other pair. Thus, in this experiment infants saw 4 objects over the two test trials, but they belonged to only two different categories, just like in Experiment 1. Half of the participants were presented with the shoe/shoe pair in the first test trial and the other half with the ball/ball pair in the first test trial. The outcome (single-object or double-object) was counterbalanced across the two object kinds across infants. The side from which the objects were presented (left or right), the presentation order of each object in the objects pairs, the order of the outcome (single-object outcome or double object outcome first), and which object was presented in the single object outcome, were counterbalanced across infants.

2.3.1.4 Dependent Measure and Coding

The same criteria of inclusion described for Experiment 1 was followed.

2.3.2 Results

Preliminary analysis did not show any effect of presentation order, the object presented in the single outcome condition, or presentation sides of the objects. Further analyses were thus collapsed over these variables. All analyses reported are performed on log transformed looking time data (Csibra et al., 2016).

Looking times were analyzed with a 2 X 2 repeated measures ANOVA with trial type (baseline, test) and outcome (single, double) as factors (Figure 2.3). No significant main effects or interaction was observed. Planned paired-sample tests reveal no significant difference at test, but a trend was found in the baseline trials ($t(15) = 2.073, p = .056, d = 0.518$), with longer looks at the double-object outcome ($M = 12.3, SD = 7.2$) compared to the single-object outcome ($M = 9.5, SD = 8.6$).

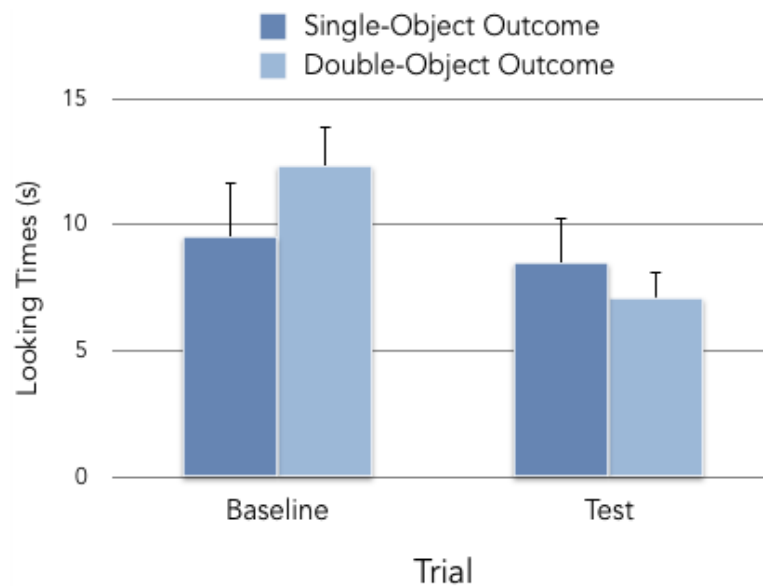


Figure 2.3. Looking times in Experiment 2 as a function of trial and outcome. Error bars depict standard error of the means.

2.3.3 Discussion

We investigated whether the success in Experiment 1 could have resulted from enhanced attention to the idiosyncratic but kind irrelevant features of the two objects involved in the event. The results of the present experiment indicate that, when the objects in the event differed on kind irrelevant visual features but belonged to the same kind, infants did not

develop an expectation that there would be two objects involved in the event. This is to be expected on the basis of our hypothesis, according to which ostensive reference induces kind-based encoding of the objects: Since there was only one kind of objects involved in these events, infants could not have formed distinct kind-based representations of them. The failure to individuate the objects in this experiment strengthen our claim that the success in Experiment 1 was based on ostensive reference triggering distinct kind-based representation of the objects, and not on general attentional enhancement.

2.4 Experiment 3 & 4: Ostensive Pointing vs. Labeling

In Experiment 1 we found that ostensive pointing to familiar objects allowed young infants to individuate these objects, presumably because it facilitates kind-based object representation. This representation, however, was only made possible by an existing kind concept that the infants could recruit when interpreting the pointing action of the communicator. Can nonverbal reference in an ostensive context open a kind-based representation even for novel objects? Such a capacity seems to be necessary for learning labels to novel objects because the label denotes not the object to which it applied but to the kind it belongs. Here we attempted to test this assumption in the context of object individuation. Chapter 4 reports a different way of testing the same question.

In Experiment 1 we tested whether ostension can induce the encoding of familiar objects as representatives of their kind. In Experiments 3 & 4 we tested whether ostensive reference can create a kind-based representation for novel unfamiliar objects, forcing them to be attached to a known kind. To test this, we follow the same basic procedure as in Experiment 1, with a few changes. Here we used two pairs of familiar objects and an unfamiliar novel object, which was not just held up and pointed to but was also labeled. Labeling was expected to assign the object to a kind, even if the object would not be recognized as a member of that kind. As in Experiment 1, two objects were brought out from behind an occluder one at a time. As before, the objects were ostensively pointed to, but the novel object was also labeled with a familiar count noun for infants of this age. In Experiment 3, this label referred to a kind different from the one the familiar object belonged, but in Experiment 4, it was referred the same kind. For example, when the familiar object was a shoe, the unfamiliar object was labeled as ‘labda’ (ball) in Experiment 3 or as ‘cipő’ (shoe) in Experiment 4. If labeling sorts the object under a kind the same way as recognition does, ostensive reference to the familiar object and

labeling the novel object should aid object individuation by promoting the establishment of two distinct kinds in the infants' mind in Experiment 3 but not in Experiment 4.

2.4.1 Methods

2.4.1.1 Participants

Sixteen 9-month-old (mean age: 9 months 12 days, age range: 8 months 15 days – 9 months 15 days, full term, healthy infants from native Hungarian speaking families were included in the final sample of each experiment. Thirteen additional infants participated but were excluded due to looking away and missing critical events (4 infants), fussiness (5 infants), and experimental error or technical errors (4 infants). Informed consent was obtained from the parents, before the study began.

2.4.1.2 Apparatus and Stimuli

The same experimental set up as in Experiment 1 & 2 was used. The familiarization and baseline trials also had the same stimuli as in Experiment 1. For the test trials, each of the objects used in Experiment 1 was paired with an unfamiliar object, such that there were two pairs of test stimuli, each pair composed of a familiar object - unfamiliar object combination. The red shoe from Experiment 1 was paired with a yellow LEGO brick lamp affixed with a yellow knob on the top, and the yellow tennis ball was paired with a wooden European style nutcracker (7 x 7 x 10 cm) . The same occluder used in Experiment 1 was used in all trials.

2.4.1.3 Procedure

Familiarization and baseline trials were identical to Experiments 1 & 2.

During the test trials, two pairs of objects were used. Each pair comprised of one familiar object and one unfamiliar object. Each infant saw only one pair of object across the two test trials. Thus, 8 infants were tested with one pair, the red shoe and the yellow LEGO brick lamp, and the other 8 infants were tested with the other pair, the yellow tennis ball and the nutcracker. The test trials were presented the same way as in Experiment 1, except the vocal accompaniment provided by the experimenter. When the hand pointed to the familiar object, the experimenter said, “Nézd!” (“Look!”). When the hand pointed to the unfamiliar object in trials where the contrasting object was a shoe, she uttered a label, “lámpa” (“lamp”) in Experiment 3 and “cipő” (“shoe”) in Experiment 4. When the hand pointed to the unfamiliar object in trials where the contrasting object was a ball, she uttered a label, “kanál” (“spoon”) in Experiment 3 and “labda” (“ball”) in Experiment 4. After the hand left, leaving the object in view, the experimenter said, “Ezt nézd! Látod?” (“Look at that! See?”) when a

familiar object was on the stage, or “Ezt nézd! Labda/Cipő” (“Look at that! [A] ball/shoe”), repeating the previously used label, when the unfamiliar object was in the stage. In all other respect the test trials were identical to, and the variants were counterbalanced the same as, Experiments 1 & 2.

2.4.2 Results

Preliminary analysis did not show any effect of presentation order, the object presented in the single outcome condition, or presentation sides of the objects in either experiment. Further analyses were thus collapsed over these variables. All analyses reported are performed on log-transformed looking time data (Csibra et al., 2016). Similar analyses to the ones performed in Experiments 1 & 2 applied to these data as well.

2.4.2.1 Experiment 3

In the two-way ANOVA, a significant main effect of outcome was observed $F(1,15) = 8.508$, $p = .011$, $\eta_p^2 = .362$ due to longer looking to double-object outcomes than to single-object outcomes (Figure 2.4). Planned paired t-tests revealed no significant difference in baseline trials but a significant difference between the looking time for single outcome and double outcome at test $t(15) = 2.255$, $p = .039$, $d = 0.564$. This significant difference was driven by longer looks to the double-object outcome ($M = 10.0$ s, $SD = 6.1$ s) compared to the single-object outcome ($M = 6.1$ s, $SD = 5.5$ s).

2.4.2.2 Experiment 4

No significant effect was found in the ANOVA or in the planned contrasts (Figure 2.5).

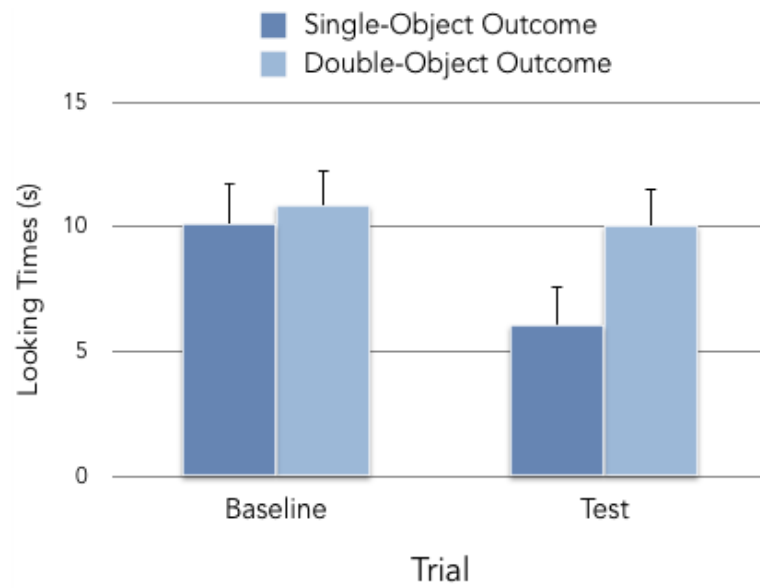


Figure 2.4. Looking times in Experiment 3 as a function of trial and outcome. Error bars depict standard error of the means.

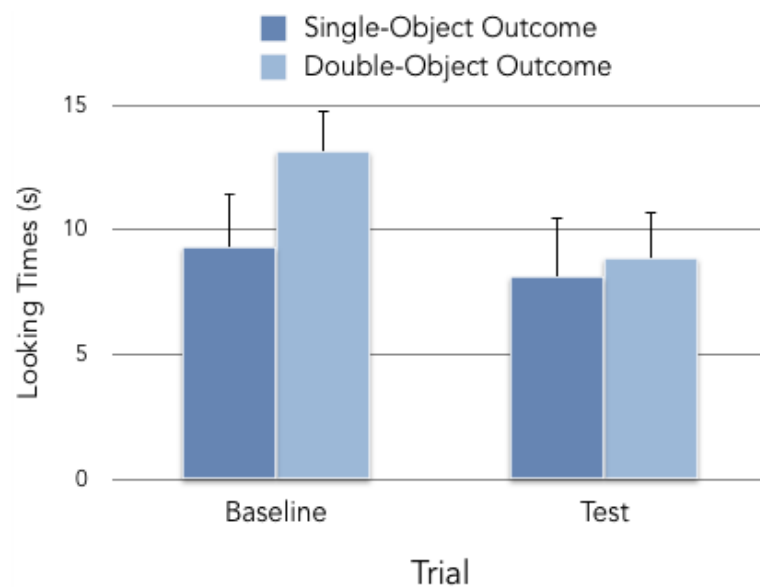


Figure 2.5. Looking times in Experiment 4 as a function of trial and outcome. Error bars depict standard error of the means.

2.4.3 Discussion

Experiments 3 & 4 addressed the question whether two different ways of identifying the kind two objects belong to would promote kind-based individuation. We know that labeling both objects (Xu, 2002) or ostensively referring to two familiar objects (Experiment 1) support object individuation – as long as the objects are labeled differently (Xu, 2002) or represent different familiar kinds (Experiment 2). On the basis of these premises, we predicted that infants posit two objects behind the occluder in Experiment 3, but would not develop numerical expectations in Experiment 4. These predictions were not, or were only partly, confirmed. While infants did not display any evidence of object individuation in Experiment 4 (as predicted), this result is difficult to interpret without the positive finding that we hoped to get for Experiment 3.

There are several potential explanations for this failure. First, our hypothesis assumed that the kind-based object representation the infants set up in response to labeling is the same type of representation that is induced by ostensive reference. This would be a precondition for applying the exclusivity logic that is required for the inference for the presence of two objects. It is thus possible that for 9-month-olds infants label-induced and ostensive-reference-induced representations are not necessarily mapped onto each other. Another possibility is that we paired an unfamiliar object with a known kind noun (in both Experiments 3 and 4), and 9-month-old infants might need more than one exposure to the label-object pairing to assimilate the new object into the kind and hence to encode the object as representing that kind. A further possibility is that the infants interpreted the labeling event, in which a familiar word was applied to an unfamiliar object, a case of mis-labeling. If this was the case, they might have refused to take it as valid information that could be used to identify the kind that the unfamiliar object belonged to (cf. Jaswal, 2004; Jaswal & Markman, 2002). We find this explanation unlikely though because infants' knowledge of the categories we used in these experiments should be quite flexible at this age.

We think that it is more likely that the infants had problems with recognizing the verbal labels we used in the experiments. While there is evidence that 9-month-olds understand some object names, among them the ones we used in our study, this evidence is based on average performance of infants (Bergelson & Swingley, 2012; 2015; Bergelson & Aslin, 2017; Parise & Csibra, 2012). If, for example, 60% of 9-month-olds recognize the majority of the words in a test battery, it is evidence for infants capacity of referential word knowledge at this age but does not guarantee that all 9-month-olds will recognize every instance of the verbal label 'ball.' Thus, our study might have just failed because not enough our participants recognized

not enough words uttered by the experimenter. In addition, an earlier study found that infants at this age are more likely to recognize a word in their mother's voice than spoken by a different person (Parise & Csibra, 2012). This, and the delivery of the labels by loudspeakers might also have contributed to the infants' difficulty of recognizing the labels in these experiments.

In sum, while Experiments 3 & 4 failed to confirm the counterintuitive predictions we drew from our hypothesis, they did not invalidate the main finding of the Chapter, namely that ostensive reference alone could induce kind-based representation of familiar objects in 9-month-old infants.

2.5 General Discussion

The theory of Natural Pedagogy posits that ostensive referential signals are understood as communicative acts meant to convey relevant information (Csibra & Gergely, 2006, 2009). Based on empirical evidence that demonstrated infants display a bias to infer that communicative reference is about a kind, we proposed that non-verbal ostensive referential signals can trigger kind-based encoding of familiar objects. Our results support our prediction by demonstrating that nonverbal ostensive reference can facilitate 9-month-old infants' success on a kind-based individuation task.

Our results are in the backdrop of previous research that has established that 9-month-old infants do not spontaneously represent familiar objects in terms of their kind unless they are prompted to form kind-based representation via explicit labelling (Xu, 2002). Some studies have shown that non-linguistic tones and emotionally expressive sounds, cannot trigger kind-based representation of objects (Xu, 2002). This is because tones, or emotional expressions are not ostensive referential signals (which we have proposed can induce kind-based representations) and that they do not provide any kind specific information. On the other hand, labeling and ostensive demonstration of object function provide both. From these studies it was difficult to say what exactly had the power to trigger kind based representations: providing kind specific information (such as labels and functions) or ostensive reference. This ambiguity arises from the facts that labeling is an ostensive referential act while at the same time provides kind defining information. So it was difficult to determine whether labeling leads to expectation of two different kinds because labels are implicitly assumed to refer to kinds, or because the ostensive delivery of labels ubiquitously comes with reference to kinds. We reasoned that this could be easily tested with familiar objects because for these objects kind defining information need not be provided, and so one can probe whether ostensive reference alone could trigger kind based encoding of the target of the communication.

The object kinds used in Experiment 1 were both from familiar kinds, for which the infants might already possess conceptual representations. In such cases ostensive reference has to only trigger existing conceptual representation of each object in order to generate kind-based representation of them. The results from Experiment 1 indicated that the ostensive reference did trigger kind-based encoding of the referred objects, allowing the infants to individuate two distinct objects. Nevertheless, the fact that ostensive reference is required for kind-based individuation of familiar objects at this age suggests that generating this type of representation of known exemplars is not an automatic process. For adults, task demands alone may trigger kind-based representations of objects. For infants, kind representations seem to come online only with ostensive reference even when the objects involved exemplars of familiar kinds.

Yet, the necessity of ostensive reference for triggering kind-based representation does not mean that ostensive reference alone would be sufficient to establish discrete kind representations. It is unlikely that the infants would have succeeded at individuating between two unfamiliar objects belonging to two unfamiliar kinds in a similar task merely because both the objects were ostensively referenced. For successful individuation, ostensive reference has to not just trigger kind-based representations but provide information that can evoke separable kind representations for the two objects. Ostensive reference without kind defining predicates would not be able to establish distinct conceptual representations.

In Experiments 3 and 4 we attempted to test whether ostensive reference, together with familiar labels, could trigger kind-based representation for novel objects. However, infants were unsuccessful at individuation in Experiment 3. Thus, these experiments did not work out as we predicted. In Chapter 4, we probed the same question with older children, utilizing a different paradigm and measurement technique.

Chapter 3

Acquiring generic knowledge without induction in infancy

3.1 Introduction

Generic knowledge is information stored about properties of kinds or classes of entities (Prasada, 2000). Such knowledge (for example, our knowledge that birds have wings) is formed not about particular entities, but about a whole kind or category. Possessing such knowledge allows one to make inferences about particular entities belonging to that kind (for example, a bird of an unfamiliar species is expected to have wings), though these inferences may not necessarily be correct (e.g., the now extinct moa species were birds without wings).

3.1.1 Two Ways of Acquiring General Knowledge

There are two fundamentally different ways to acquire generic knowledge: by inductive learning or by comprehending linguistically conveyed generic statements. The first option, inductive learning, is built on evidence collected about particular entities belonging to a kind and involves generating hypotheses from this evidence to the whole kind. Such hypotheses are essentially statistical in nature, though they may also rely on prior knowledge about the domain in question (Tenenbaum, Griffiths, & Kemp, 2006). Inductive learning is widely studied in both humans and non-human animals (e.g., Rakoczy et al., 2014), and evidence shows that such learning processes are present very early in development (Gweon, Tenenbaum, & Schulz, 2010; Schulz, 2012; Xu & Garcia, 2008). The acquisition of generic knowledge by induction can be well characterized as a rational Bayesian learning process, in which the validity of the acquired knowledge is guaranteed by the statistically valid inferences drawn from the evidence (Tenenbaum et al., 2006).

The second way of acquiring generic knowledge is by linguistic communication. Generic sentences (such as “Koalas sleep 20 hours a day”) state something directly about a kind, hence they can transmit generic knowledge to others without referring to evidence about particular entities (Carlson & Pelletier, 1995; Prasada, 2000). In fact, one can acquire such knowledge from others without having any personal experience with members of the kind (without ever having seen a koala, let alone measuring the duration of their sleep). This route of acquiring generic knowledge seems to be restricted to humans, who can produce and comprehend generic sentences. The validity of the knowledge acquired this way is warranted by, and should be dependent upon, the epistemic trust bestowed on the person who expresses it in a generic statement.

Generic knowledge, whether it is acquired by induction or by communication, represents a “primitive” mode of generalization that does not appeal to explicit quantification (Leslie, 2008; Collins, 2015). In particular, when such knowledge is entertained about a kind

of entity, it does not entail universal quantification, i.e., it does not imply that all members of the kind will exhibit the property in question (not all koalas sleep 20 hours a day; not all birds have wings). Consequently, generic knowledge allows exceptions, and counterexamples do not necessarily invalidate it. However, inductively generated generic hypotheses should be more vulnerable to counterexamples than those acquired by communication. This is because inductive acquisition of generic knowledge is based on statistical evidence, which should be sensitive to the properties of the sample (Tenenbaum & Griffiths, 2001), while generic knowledge learned from generic expressions is a quasi-normative fact that may be contradicted but not disqualified by counterevidence (Gelman, 2004; Leslie, 2008).

A further difference between the two ways of learning generic knowledge is that the second option is available only to creatures that can interpret linguistic expressions of genericity. Developmental data suggest that 2-year-olds can already understand generic expressions, well before mastering linguistic quantifiers (Gelman & Raman, 2003). A plausible assumption is that younger children, who lack sufficient linguistic skills to comprehend verbal generic statements, acquire their generic knowledge entirely through inductive learning. However, Csibra and Shamsuddeen (2015) proposed that nonverbal communication could also directly convey generic information akin to how generic statements in language work. They proposed that ostensive reference to a particular object, for example in the form of deictic signals, can be interpreted as indirectly referring to the kind to which the highlighted object belongs. That is, if the specific object that is ostensively referred to is treated as a representative of its kind rather than as an individual object of its own, communicative demonstration about the object's property can be taken as applicable to its kind, or, in other words, as expressing generic knowledge.

3.1.2 Sensitivity to Counterevidence

The aim of the present study was to investigate the above proposal, i.e., whether human infants interpret communicative demonstrations of object properties as expressions of generic knowledge. While there is evidence that child-directed communication modulates the learning of object properties, such effects are usually interpreted as arising from the modification of the parameters of inductive learning through making infants interpret the sampling process differently from situations in which they collect information outside communication (Gweon et al., 2010). Thus, whether children interpret the demonstration of object properties as generic statements or simply modulate the parameters of the underlying inductive learning procedure, is not clarified by the existing literature.

We illustrate the contrast between these options with a study by Butler and Markman (2012), which explored whether communication modulates the strength of children's generalization of object properties. A novel object, labeled 'a blicket,' was introduced to preschoolers, and a dispositional property of this object was demonstrated to them in one of three different ways. For the children in the 'communicative (pedagogical) condition,' the experimenter ostensibly demonstrated that the blicket was magnetic by showing that it could lift paperclips from the surface of a table. The children in the 'intentional condition' observed the experimenter deliberately but non-communicatively use the blicket to lift paperclips off the table. The children in the 'accidental condition' saw the experimenter accidentally drop the blicket onto a pile of paperclips, which allowed them to observe the magnetic properties of the object. In each condition, after the demonstration, the experimenter placed 10 more identical objects on the table and left the room after saying "here are some more blickets, go ahead and play." Importantly, none of these additional blickets were magnetic. The number of attempts the children made to pick up paperclips with these objects was taken to indicate the strength of their expectation that these objects would also be magnetic, potentially stemming from generalization of the magnetic property from the demonstration blicket to other members of the 'blicket' kind. The children in the communicative condition persisted longer and attempted to elicit the property from more of the additional blickets, than the children in either of the non-ostensive conditions (Butler & Markman, 2012). Later studies found that, under favorable conditions, even 3- and 2-year-olds displayed the same effect (Butler & Markman, 2016; Butler & Tomasello, 2016).

Butler and Markman argued that these results support Csibra and Gergely's (2006; 2009) proposal that information expressed in communication is more likely to be generalized beyond the immediate context, and beyond the particular objects at hand, than information gained from observing a non-communicative action. However, as we explicated above, there are two possible learning mechanisms that would account for such an effect: inductive generalization (IG), and interpreting the communication as nonverbally expressing the genericity of the demonstrated property (nonverbal generics, NG). We discuss these two options in turn.

[IG] Butler and Markman's results can be explained by the proposal that child-directed communication simply increased the strength of generalization that the children would have made. Information learned about even a single object ('this blicket is magnetic') may have been sufficient to generate the hypothesis that the observed property may also apply to other objects of the same kind without going through iterative

generalization processes with additional exemplars. In this account, communication would strengthen the initial hypotheses by explicitly marking the property and/or the exemplar as providing a strong sample for generalization (Gweon et al., 2010). The production of this hypothesis would then be followed by hypothesis testing on further exemplars until sufficient data is gathered to reach a conclusion on whether the property is generic to the kind. In Bayesian terms, the strength of the inductive hypothesis serves as a prior for incorporating further evidence: positive evidence increases, and negative evidence decreases the posterior belief in the validity of the hypothesis. In the Butler and Markman procedure, the inert test blickets exposed the children to a series of counterevidence against the inductive hypothesis (i.e., that 'blickets are magnetic'), which eventually should have resulted in discarding it. However, if the communicative demonstration made the initial hypothesis about the generalizability of the object property stronger, the children would have needed more counterevidence for discarding it, which would explain their persistent attempts on the inert blickets in the communicative condition. According to this model, the difference between learning from communicative vs. non-communicative contexts is one of quantity, where beginning with a stronger hypothesis in the communicative condition necessitates more negative evidence to discard the hypothesis that the property is generalizable.

[NG] The second account proposes that nonverbal ostensive communication could also convey generic information akin to how generic statements in language work (Csibra & Shamsudheen, 2015). By this account, the children in the communicative condition of the Butler & Markman (2012) study interpreted the communicative reference to the demonstration object as referring to the 'blicket' kind, and thus learned from the demonstration not (only) about the demo blicket, but fast-mapped the property of magnetism directly to the kind. In other words, they interpreted the demonstration the same way as if they had heard the generic sentence 'Blickets are magnetic' (or 'Blickets can pick up paperclips'). When the children were then presented with further blickets, they inferred (deductively, rather than inductively) that, blickets being magnetic, these blickets would also display the magnetic property. Because generic knowledge tends to be resistant to counterevidence (Gelman, 2004; Leslie 2007; 2008), coming across an inert blicket would have not led them to infer that, after all, blickets were not magnetic, but instead to conclude that the inert object was a dysfunctional or non-representative blicket. That is, they might have discarded the

negative evidence rather than rejecting the knowledge they acquired about the blicket kind through communicative demonstration. In contrast, in the non-communicative conditions, the children must have followed the route of inductive generalization, as described by the IG account.

In sum, both the IG and the NG accounts propose that learning occurs in both communicative and non-communicative contexts. IG claims that the very same information, i.e., information about the specific demonstration object, is learned in both contexts, and it is merely the strength of the inductive generalization hypothesis that differs between contexts. In contrast, NG claims that learning from communication and learning from observation are qualitatively different because in ostensive contexts children learn directly about an object kind.

This qualitative difference in how the two accounts propose generic knowledge is acquired leads to distinct predictions on how children are expected to treat counterexamples. According to the IG account, counterexamples (objects of the same kind that do not display the generalized property) should be treated as evidence against the hypothesis that the property in question is generic. In contrast, according to the NG account, counterexamples should have hardly any effect on the already established knowledge that the property is generic, and any evidence that counters this generic knowledge would likely be discarded as an exception or anomaly. Thus, the two accounts make different predictions on what children would expect from further exemplars of the same kind. IG predicts decreasing exploration of consecutive inert objects, reflecting reduced confidence in the generalization hypothesis, and eventually abandoning the expectation that further objects would display the demonstrated property. In contrast, NG predicts sustained exploration of the inert exemplars because failing to elicit the property from some objects would not necessarily weaken the belief that the object kind has the property in question. The data reported by Butler and Markman (2012) cannot adjudicate between these predictions because all the objects to be explored were given to the children in a single lot, which did not allow the assessment of how they responded to each counterexample.

3.1.3 The Present Study

We developed a paradigm that investigated this question by separating the instance of counterevidence from the test that assessed the effect of experiencing the counterevidence. We achieved this separation by giving two inert objects, the counterexample and the test, one after the other, to the infants. After being exposed to either communicative or non-

communicative demonstration of an object property on the demo object, infants were given an inert object as a counterexample, and then a further inert object as test to assess the effect of the counterevidence they had just encountered. We tested the following two predictions derived from the two accounts (see Figure 3.1):

- 1) IG predicts more attempts on the counterexample in the communicative condition than in the non-communicative condition, because infants would start with a stronger inductive hypothesis after communicative than after non-communicative demonstration (Figure 3.1A). (In effect, this prediction states that, had Butler and Markman (2012) given a single generalization blicket to their participants, they would have found the same effect.) NG does not predict such a difference because it hypothesizes qualitatively (rather than quantitatively) different expectations between the conditions about further exemplars.

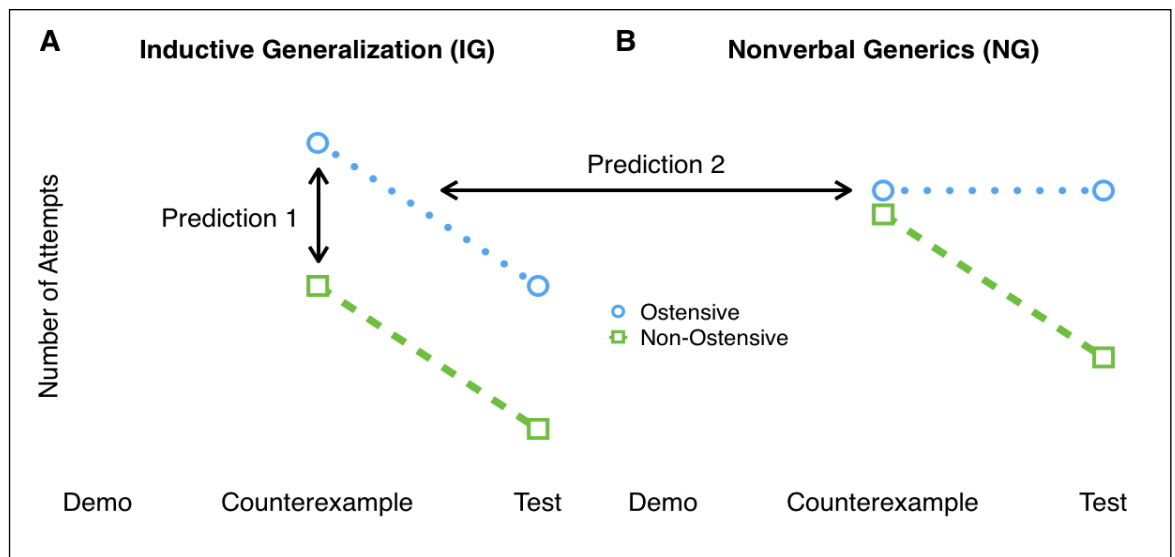


Figure 3.1. Predictions drawn from two different accounts of generic learning about the expected number of actions infants would make on inert objects. IG predicts a difference in the number of attempts on the counterexample (Prediction 1), and the two accounts predict different slopes of change from the counterexample to the test object in the Ostensive condition (Prediction 2).

- 2) IG predicts fewer attempts on the test object than on the counterexample in both the communicative and the non-communicative conditions, because the counterexample should weaken the hypothesis of generalizability irrespective of how this hypothesis has been induced. In contrast, according to the NG account,

the number of attempts should decrease from the counterexample to the test only in the non-communicative condition, because the counterevidence would not affect the belief, acquired from communicative demonstration, that the property is generic. In other words, the two accounts predict different slopes of change in the number of attempts between the counterexample and the test (Figure 3.1B).

We performed 4 experiments with 18-month-old infants to investigate these predictions. For ease of comparison, Table 1 summarizes the differences across these experiments.

	Experiment 1	Experiment 2	Experiment 3	Experiment 4
Objects	Lego lamp set + Elephant set	Lego lamp set	Lego lamp set	Lego lamp set
Object colors	Same for Demo and Counterexample	Same for Demo and Counterexample	Same for Demo and Counterexample	All are different
Between-subjects conditions	Ostensive vs. Non-Ostensive	Ostensive vs. Non-Ostensive	(Ostensive only)	Ostensive vs. Non-Ostensive
Within-subjects conditions	Baseline vs. Active	(Active only)	(Active only)	(Active only)
Object labels	None	All objects	Demo object only	All objects
Tests	Generalization	Generalization	Generalization	Generalization + Choice

Table 1. Comparison of differences across the experiments.

3.2 Experiment 1

We tested the hypothesis that in communicative contexts (as opposed to non-communicative observational situations) infants acquire generic knowledge about an object kind from the demonstration on a single exemplar. If this hypothesis is correct, they should expect novel exemplars of the same kind to possess the demonstrated property, even if they fail to elicit the property from some exemplars of the kind. We employed a version of the so-called inductive generalization task (e.g., Baldwin, Markman, & Melartin, 1993) with two

extensions: we varied the nature of demonstration (ostensive vs. non-ostensive), and we tested generalization on a further potential exemplar after the infants received counterevidence.

Eighteen-month-old infants observed a target action on a novel object performed either in an ostensive or in a non-ostensive but intentional manner. This action either elicited (active condition) or did not elicit (baseline condition) a non-obvious property. The infants were then allowed to explore the original demo object before being observed on how persistent they were in trying to elicit the property from two inert objects: a counterexample, which looked identical to the demonstration object, and a test object, which differed only in color. The dependent variable was the number of target actions performed on each object. This is a reliable and well-established measure for the strength of infants' expectation that an object will possess a property, given they have observed another exemplar of the same kind to display the property (e.g., Baldwin et al., 1993; Graham, Kilbreath, & Welder, 2004).

3.2.1 Methods

3.2.1.1 Participants

Thirty-two 18-month-old infants (mean age = 18.05 months, range: 17.5 to 18.5 months) from native Hungarian speaking families were included in the final sample (16 each in the Ostensive and the Non-Ostensive conditions). Thirteen additional infants were excluded for not making any attempts to operate the demo object or failing to elicit the property from it in the Active condition (7 infants), experimenter error (5 infants), and parental interference (1 infant).

3.2.1.2 Materials

Two sets of novel objects were used: a set of four Lego brick lamps, and a set of four elephant-shaped squeaky objects. Each set had one active object, which could manifest a property when acted upon in a specific manner, and three inert objects (two of them identical to the demonstration object and one of a different color), whose functional capability had been disabled without affecting the manipulability of the objects. The Lego brick lamp ('Lego lamp') had a knob affixed in the middle, which, when pushed, lit up the translucent white top half of the brick. The elephant shaped object ('toy elephant') produced a squeaky noise when squeezed. For each infant, one set was used in the Active condition, and the other in the Baseline condition, counterbalanced across participants.

3.2.1.3 Design

Conditions were separated along two factors. As a between-subjects factor, the infants participated either in the Ostensive condition or in the Non-Ostensive condition, which differed in the manner of demonstration. As a within-subjects factor, all the participants were subjected to two object-set conditions, Active and Baseline, in which the demo object did or did not produce an effect during the demonstration phase, respectively.

3.2.1.5 Procedure

Each infant participated in two (Active and Baseline) conditions. The order of the conditions was counterbalanced across infants. At the end of the procedure of the first condition, the infant and the parent left the testing room, and the infant was entertained with distraction games in the reception room for 5 minutes before the next condition commenced. Each condition consisted of a demonstration phase and a test phase.

Demonstration phase, Ostensive condition. The infants and their caregivers were led to the testing room by Experimenter 1 (E1). She seated the infant on the caregiver's lap next to a table, and then sat across the table from them. She addressed the infant (in Hungarian) "Hello, [infant's name]," and then picked up an object from below the table and directed the infant's attention to it by saying "Look!". She then proceeded to demonstrate the target action on the object three times, looking up and making eye-contact with the infant between each demonstration. Note that, in the Active condition but not in the Baseline condition, each of these actions produced an effect (light for the Lego lamp and a squeaky sound for the toy elephant). E1 then placed the object on her side of the table, out of the infant's reach, said she would be right back, and stepped out of the room. She came back into the room 15 seconds later to administer the test phase.

Demonstration phase, Non-Ostensive condition. The infants and their caregivers were led to the testing room by E1. Experimenter 2 (E2) was already in the room, sitting at the table and reading a book. E1 seated the infant on the caregiver's lap across the table from E2, and left the room. Once E1 left, E2 put her book down, picked up an object from below the table, and demonstrated the target action on the object three times. Each of these actions produced an effect in the Active condition, but not in the Baseline condition. E2 did not make eye contact or indulge in any other communicative attempts with the infant before, during, or after the target action was demonstrated. After the demonstration, she placed the object on her side of the table, out of the infant's reach, and stepped out of the room. Fifteen seconds later E1 came back into the room to administer the test phase.

Test phase. The test phase consisted of three trials and was administered by E1 in a non-ostensive manner in both the Ostensive and the Non-Ostensive conditions. E1 did not make eye contact or talk to the infant at any point during the test phase. The infants were given the three different objects in a fixed order across the three trials: first the demo object, second the counterexample, and finally the test object. E1 sat down across the table from the infant, picked up the demonstration object from her side of the table, and placed it in front of the infant. The infant was given 20 seconds to explore the object before it was taken away and placed back on the experimenter's side of the table. E1 then took out an identical looking inert toy (the counterexample) from below the table and placed it in front of the infant. The infant was given 20 seconds to explore the object, before it was taken away and placed on the experimenter's side of the table. Finally, E1 took the differently colored inert toy (the test object) from under the table and placed it in front of the infant. Again, the infant was given 20 seconds to explore the test object.

3.2.1.6 Coding and Reliability

The number of attempts made on the objects in each trial during the test phase was coded from video recordings. An action was counted as an attempt only when it was identical or similar to the demonstrated action, and could have produced the demonstrated property, had the toy not been deactivated. Each participant's number of attempts during each trial of the test phase was also coded by a second coder who was blind to the study hypothesis. Inter-coder agreement was tested using intra-class correlation coefficient tests, which was high for all three trials of the test phase in both the Baseline and the Active conditions (ICC values ranging from .993 to 1.000).

3.2.2 Results

A three-way mixed ANOVA with object set condition (Active vs. Baseline) and trial (demo object, counterexample, test object) as within-subject factor, and communicative condition (Ostensive vs. Non-Ostensive) as between-subject factor revealed a significant main effect of object set condition ($F(1, 30) = 12.39, p = .001, \eta_p^2 = .292$), with infants performing more attempts in the Active condition ($M = 4.5, SD = 3.1$) than in the Baseline condition ($M = 2.7, SD = 3.1$). Significant main effects were also obtained for trial ($F(2, 60) = 3.49, p = .037, \eta_p^2 = .104$), with infants performing more attempts on the counterexample ($M = 4.0, SD = 3.3$) than on the test object ($M = 3.0, SD = 3.1$), with the number of attempts on the demo object falling in between ($M = 3.8, SD = 3.1$). This ANOVA did not find any effect of communicative condition on infants' exploration of objects (Figure 3.2).

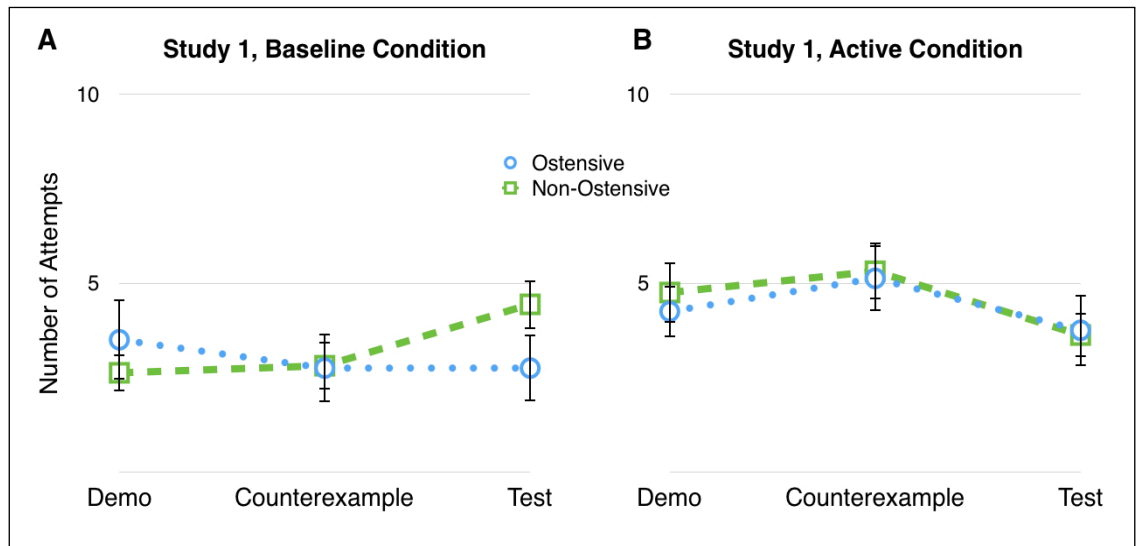


Figure 3.2. The mean number of attempts on each object in the test phase of Experiment 1 as a function of condition. Error bars indicate standard error of the mean.

The IG account predicted that, in the Active condition, infants should show more attempts on the counterexample in the Ostensive than in the Non-Ostensive condition. This prediction was not confirmed ($t(30) = 0.16, p = .870$; see Figure 3.2B). The NG account predicted a reduction in the number of attempts performed on the test object after infants had observed a non-ostensive demonstration, but not when they had observed an ostensive demonstration. This prediction was not confirmed either: a 2x2 ANOVA with trial (counterexample, test object) and communicative condition as factors (within the Active conditions) resulted only a main effect of trial ($F(1,30) = 9.49, p = .004, \eta_p^2 = .240$), showing that the number of attempts dropped from the counterexample to the test object by similar amount in the Ostensive (from 5.1 to 3.8) and the Non-Ostensive (from 5.3 to 3.6) condition (Figure 3.2B).

3.2.3 Discussion

The participants of Experiment 1 performed more target actions in the Active than in the Baseline condition regardless of whether the manner of demonstration was ostensive or non-ostensive. This result clearly shows that the infants paid attention during the demonstration and learned from it, whether or not it was performed in a communicative manner. That the children performed more target actions on the objects in the Active condition than in the Baseline condition is not surprising given the lack of effect of both the experimenter's and their own actions in the Baseline condition.

The pattern of results in the Active condition did not confirm the predictions drawn from either account. In contradiction to Prediction 1, drawn from the IG account, the infants did not perform more actions on the counterexample in the Ostensive than in the Non-Ostensive condition, suggesting that the strength of their hypothesis that the property is generalizable did not depend on the manner of presentation. However, the infants displayed a similar decrease in their exploration of the test object after the counterexample in both the conditions. This pattern is consistent with Prediction 2 drawn from the IG account but not with the one drawn from the NG account. In other words, we found no evidence that the infants' learning was modulated by communication in any way (Figure 3.2B). Such a conclusion would imply that the beneficial effect of ostensive demonstration on generalization might not be observable at 18 months of age, and the findings that even younger infants encode information acquired from ostensive demonstration differently from non-ostensive observations (e.g., Futó, Téglás, Csibra, & Gergely, 2010; Hernik & Csibra, 2015; Király, Csibra, & Gergely, 2013; Kupán et al., 2017; Träuble & Bätz, 2014; Yoon, Johnson, & Csibra, 2008) might not indicate the operation of cognitive mechanisms that would serve generalization.

However, before we conclude that ostensive demonstration of object properties is not interpreted by 18-month-olds as revealing generic properties, we should consider other potential explanations for this failure. Apart from the inclination to interpret ostensive demonstration as kind-generic, certain other capacities might also be required to extend the expectation of the demonstrated property to the additional exemplars given at test. In particular, infants must be able to treat the counterexample and the test object as members of the same kind as the demo object. Our procedure assumed that they would do so; after all, the counterexample had the very same surface features as the demo object, and the test object differed only in color from them. Given that children already exhibit the so-called 'shape bias' by 18 months of age (Booth, Waxman, & Huang, 2005; Hupp, 2008; Samuelson & Smith, 2005; Smith, 2000), identify artifacts of similar or identical shapes as members of the same kind, disregarding color and texture differences (Booth et al., 2005; Gershkoff-Stowe & Smith, 2004; Graham & Poulin-Dubois, 1999), and also expect them to share functional properties (Graham et al., 2004; Graham & Diesendruck, 2010; Switzer & Graham, 2017; Welder & Graham, 2001), we expected that 18-month-olds would be able to infer that the demo object, the counterexample, and the test object were of the same kind.

However, studies indicate that, when objects are similar in shape but do not display similar functions, young children are less likely to consider them as members of the same kind. While similar shape may indicate a common kind, the child might be forced to discard this

hypothesis when faced with identical or similar exemplars that do not share a common function. For instance, allowed to freely categorize novel objects into two groups, children grouped the objects on the basis of common function rather than common shape (Butler & Markman, 2014; cf. Booth, Schuler, & Zajicek, 2010). Younger children also do not consider similar shape as an absolute marker of kind membership (Madole, Oakes, & Cohen, 1993; Träuble & Pauen, 2007; Ware & Booth, 2010). Since our task provided no other cues to kind membership, the children might not have persisted in attempting to elicit the property from an inert object because they were not certain that it was the same kind as the demo object, even if they interpreted the ostensibly demonstrated property as generic. In other words, the absence of effect in the counterexample might have provided them with evidence that it was not the same kind of object as the demo object, and that visual similarity was not a reliable source of information to establish membership of this kind.

Thus, two explanations compete to explain the lack of differences between the Ostensive and Non-Ostensive conditions in Experiment 1: (1) 18-month-olds fail to interpret ostensive demonstration as referring to the object kind represented by the demo object (failure of ‘intension’), and (2) 18-month-olds do not make strong inference to kind membership from shared visual features (failure of ‘extension’). To adjudicate between these explanations, we performed a second experiment, in which we made manifest for infants that the objects in question belonged to the same kind.

3.3 Experiment 2

In Experiment 1, the infants received no strong cues that guaranteed the demo, counterexample, and test objects were of the same kind. Such an inference of shared kind membership is a necessary precondition to extend generic properties from one object to others. In fact, the task in Experiment 1 expected the infants to perform two types of inferences (jointly or consecutively): (1) that the counterexample and test object belong to the same kind as the demo object, and (2) that the demonstrated property is generic to this kind. While the development of the ability to draw the first type of inference is an important question on its own right, our investigation intended to address only the second type of inference. To ensure that our results reflect whether infants generated this second type of inference, we decided to supply them with information that made the first type of inference unnecessary. In other words, in Experiment 2, we made explicit for the infants that all objects were of the same kind.

Apart from function, labels are also reliable indicators of kind membership: shared labels strongly indicate that the objects are of a common kind. In fact, it has been suggested

that the primary developmental function of object names (and names of other entities) is to unambiguously define the extension of the concept denoted by the name (Gelman, 2004). Studies have consistently found that young children are more likely to extend a novel property to other objects if they have a common name (e.g., Graham et al., 2004; Keates & Graham, 2008; Switzer & Graham, 2017; Welder & Graham, 2001). In Experiment 2 we thus introduced a labeling phase, during which all the three objects were ostensibly labeled using a common count noun before the experiment proper started. We expected the labeling to provide definite knowledge that the objects shared kind membership.

3.3.1 Methods

This experiment repeated the Active condition of Experiment 1 with the addition of a labeling phase before demonstration. The Baseline condition was dropped as our main interest was in the effect of ostensive communication on learning, and this condition did not provide learning opportunities to the infants. Thus, each infant participated in a single condition, either corresponding to the Ostensive-Active or to the Non-Ostensive-Active condition of Experiment 1.

3.3.1.1 Participants

Thirty-two 18-month-old infants (mean age = 18.09 months, range: 17.5 to 18.5 months) from native Hungarian speaking families were included in the final sample (16 in both the Ostensive and the Non-Ostensive condition). Thirteen further infants were excluded due to fussiness (1 infant), uncooperative behavior (1 infant), experimenter error (1 infant), failing to elicit the effect from the demo object (9 infants), parental interference (1 infant), and familiarity with the object (mentioned by a parent after the experiment, 1 infant).

3.3.1.2 Materials

The set of three Lego lamps, employed in Experiment 1, was used.

3.3.1.3 Procedure

A labeling phase was introduced before the demonstration phase. Each infant received a labeling phase, a demonstration phase and a test phase.

Labeling phase. The labeling phase was conducted in the reception area before the infants entered the testing room. E1 presented the infant with an open box, tilting and displaying the set of three Lego brick lamps. She then labeled the objects, saying (in Hungarian) “Hi [infant’s name], do you see these *bukucies?* These are *bukucies!*”. (‘Bukuci’ is a

phonotactically valid Hungarian pseudo-word.) The labeling phase was identical for the Ostensive and Non-Ostensive conditions.

Demonstration phase, Ostensive condition. Just as in Experiment 1, E1 led the infant and their caregiver to the testing room, taking the box containing the objects with them. She seated the infant on the caregiver's lap at a table, sat across from the infant, and placed the box under the table on her side. The rest of the procedure was identical to that of Experiment 1.

Demonstration phase, Non-Ostensive condition. Like in the Ostensive condition, E1 led the infant and caregiver to the testing room carrying the box with the objects. E2 was already in the room, sitting at the table engaged in reading a book. E1 placed the box on the table, seated the infant on the caregiver's lap across the table from E2, and then left the room. Once E1 had left, E2 put her book down on the floor, transferred the box with the objects under the table, picked up the demo object from below the table, and proceeded the same way as in Experiment 1.

Test phase. The test phase was carried out the same way as in Experiment 1.

3.3.1.4 Coding and Reliability

The coding of the test phase was performed the same way as in Experiment 1. Inter-coder agreement was tested using intra-class correlation coefficient tests, which was high for all three trials of the test phase (ICC ranging from .995 to .999).

3.3.2 Results

A two-way mixed ANOVA with trial (demo object, counterexample, test object) as within-subject factor and communicative condition (Ostensive vs. Non-Ostensive) as between-subject factor revealed significant a main effect of trial $F(2, 60) = 5.25, p = .008, \eta_p^2 = .149$. The interaction between trial and communicative condition was close to being significant: $F(2, 60) = 2.58, p = .084, \eta_p^2 = .079$.

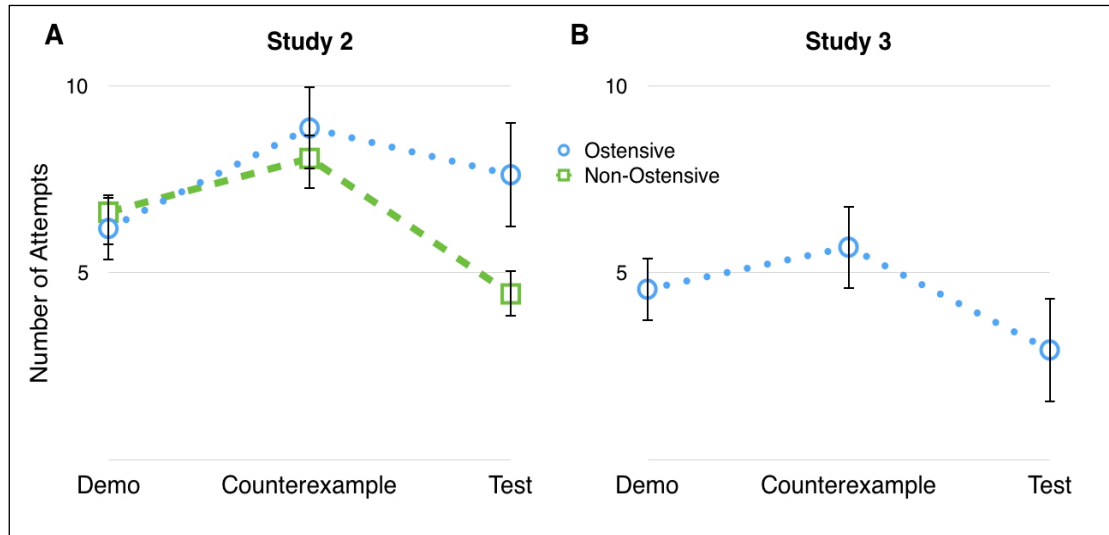


Figure 3.3. The mean number of attempts on each object in the test phases of Experiments 2 & 3 as a function of condition. Error bars indicate standard error of the mean.

A comparison of the number of attempts on the test object in the Ostensive and Non-Ostensive conditions by independent-samples t-test revealed a significant difference $t(20.3) = 2.09, p = .049$ (where variances were unequal, degrees of freedom were adjusted accordingly), with number of attempts higher in the Ostensive condition than in the Non-Ostensive condition (Figure 3.3A). Contrary to Prediction 1 from the IG account, there was no significant difference between the two conditions in the number of attempts performed on the counterexample $t(30) = 0.59, p = .559$. The difference in the number of attempts on the test object between the two conditions was driven by a significant drop from the counterexample ($M = 8.1, SD = 3.3$) to the test ($M = 4.4, SD = 2.4$) in the Non-Ostensive condition: $t(15) = 4.24, p = .001$, but not in the Ostensive condition (from $M = 8.9, SD = 4.4$ to $M = 7.6, SD = 5.6$): $t(15) = .98, p = .341$. This result confirmed Prediction 2 by the NG account.

3.3.3 Discussion

When all the three objects were explicitly identified as members of the same kind by labeling them prior to the demonstration, 18-month-olds who had received ostensive demonstration did not decrease their attempts to elicit the novel property from the test object despite having experienced failure with the counterexample. This was in contrast to the infants in the Non-Ostensive condition, who engaged in fewer attempts on the test object than on the counterexample. This result supports Prediction 2 drawn from the NG account against

the one drawn from the IG account and is also in line with how older children show resistance to counterevidence when given novel information via ostensive demonstration (Butler & Markman, 2012, 2014; Butler & Tomasello, 2016). Clearly, the negative evidence provided by the counterexample did not influence how the infants in the Ostensive condition expected the test object to behave.

This pattern of results is also consistent with the proposal that infants drew different inferences from the two types of demonstration: an inductive hypothesis in the Non-Ostensive condition and inference to genericity of the property in the Ostensive condition. Learning via inductive generalization (IG) should result in decreased persistence on the test object upon obtaining evidence contrary to the initial hypothesis formed from observing the experimenter and acting on the demo object themselves (Prediction 2). However, only the infants who received non-ostensive demonstration behaved this way. Also, according to the IG account, the infants should have persisted more on the counterexample after receiving ostensive as opposed to non-ostensive demonstration (Prediction 1). Yet, the infants in the Ostensive and Non-Ostensive conditions attempted to elicit the property from the counterexample equivalent number of times.

The marked difference naming produced between the two conditions in Experiment 2 indicates that the results of Experiment 1 were not due to 18-month-olds failing to be affected by ostensively presented information. Rather, in Experiment 1 the infants were failing to take similar shape as incontrovertible evidence that the counterexample and test object belonged to the same kind as the demo object.

While the results of Experiment 2 confirm the NG account, the difference between Experiments 1 and 2 raises questions about the role of object labels in generalization. Labels were introduced in Experiment 2 to mark the objects as belonging to the same kind, but their effect can be accounted in other ways as well. In particular, Butler and Tomasello (2016) proposed that linguistic labels directly cue children that the subsequent communication conveys generic information about the labelled objects. They proposed that labeling marks an object as belonging to a category that is culturally relevant, which in turn generates inferences that culturally relevant, generalizable, and kind defining information is about to be communicated to them. Experiment 3 explored this possibility.

3.4 Experiment 3

Butler & Tomasello (2016) proposed that labeling objects is a pragmatic cue that strengthens children's learning in ostensive contexts by indicating to the child that the ensuing communication conveys a generalizable, central property of a culturally relevant kind. This

would suggest that the effect of labeling in Experiment 2 was not due to labels reliably identifying shared kind membership of the objects. Rather, attaching a label to the demo object might have promoted and strengthened the bias to learn generalizable information from the subsequent ostensive communication.

Experiment 3 attempted to test which of these roles labels play in promoting generalization. In Experiment 2, the infants were presented with a common label for all the three objects. In Experiment 3, we labeled only the demo object, and thereby avoided identifying the counterexample and test object as members of the same kind as the demo object. If labeling prior to the demonstration indicates that the subsequent ostensive demonstration would impart kind-relevant information, and this itself facilitates generalization, then infants should show similar persistence on the test object as the infants who received ostensive demonstration in Experiment 2. If, however, labeling works by identifying kind membership, then not labelling the counterexample and test objects should result in lack of persistence on the test object.

3.4.1 Methods

A single group of infants was tested the same way as in the Ostensive condition of Experiment 2, with the only difference being in which objects were labelled during the labeling phase.

3.4.1.1 Participants

Sixteen 18-month-old infants (mean age = 18.12 months, range: 17.5 to 18.5 months) from native Hungarian speaking families were included in the final sample. Six further infants, who failed to elicit the effect from the demo object with their actions were excluded.

3.4.1.2 Procedure

The only difference from Experiment 2 was that only the demo object was labeled during the labeling phase in the reception area (“Hi [infant’s name], do you see this bukuci? This is a bukuci!”). The other two objects were not present at the labeling phase but were already hidden under the demonstration table. E1 walked with the infant and parent, carrying the demo object, from the reception room to the testing room, and then proceeded with the experiment the same way as in the Ostensive condition of Experiment 2.

3.4.1.4 Coding and Reliability

The coding of the test phase was performed the same way as in Experiments 1 and 2. Inter-coder agreement, quantified using intra-class correlation coefficients, was high (ICC ranging from .990 to 1.000).

3.4.2 Results

A repeated measures one-way ANOVA with trial (demo object, counterexample, test) as within-subject factor revealed a significant main effect: $F(2, 30) = 8.98$, $p = .001$, $\eta^2 = .374$ (Figure 3.3B). A follow-up t-test found a significant drop in the number of attempts on the test object ($M = 2.9$, $SD = 2.3$) compared to the counterexample ($M = 5.7$, $SD = 2.4$): $t(15) = 3.94$, $p = .001$. This result indicates that ostensive demonstration on a labelled object is not sufficient to make infants resistant to counterexamples. A similar conclusion can be drawn from the comparison between the number of attempts performed on the test object in this experiment and in the Ostensive condition of Experiment 2 (compare Figure 3.3A and 3.3B). The infants in the present experiment made significantly fewer attempts on the test object than those in the ostensive condition of Experiment 2 (2.9 vs. 7.6): $t(19.8) = 3.10$, $p = .006$.

3.4.3 Discussion

Despite ostensive demonstration of the novel property of the demo object, labeling only this object (or, rather, not labelling the other objects) resulted in a drop in the number of attempts to elicit the property from the test object compared to the counterexample. We had predicted that if the role of labels were to identify objects as kind members, just labeling one of the objects prior to the demonstration would not be enough for infants to exhibit persistence on the test object. This is borne out by the comparison of the results between Experiment 3 and Experiment 2. In Experiment 2, where all the three objects were labeled with a common name, the infants who had received ostensive demonstration did not show a drop in the number of attempts to elicit the demonstrated property from the counterexample to the test object. This pattern is in contrast to the reduced number of attempts on the test object, we found in Experiment 3.

The behavioral pattern in Experiment 3 is similar to the pattern shown by the infants in Experiment 1, where they did not receive labeling in either the Ostensive or the Non-Ostensive condition. Seemingly, labeling only the demo object was similar to having no labeling at all. This comparison indicates that the difference labeling made in Experiment 2

was not by the virtue of signaling cultural relevance of the demo object. If that had been the case, we should have seen a difference between the results in Experiment 3 and those of the Ostensive condition in Experiment 1.

Our results are also in agreement with those of Butler and Tomasello (2016), who found that, for 2-year-olds, labels played the role of highlighting the range of objects to which a generic property is applicable. Two-year-olds, who were presented with ostensive demonstration of a novel property of a novel object, showed persistence in expecting the property from further similarly shaped objects only when all the objects, including the demonstration object and test objects, had been labeled with a common kind label. When the 2-year-olds were provided a label only for the demonstration object, they failed to persevere in their expectation that the test objects would also possess property, just as 18-month-olds did in Experiment 3. Our experiment suggests that, already at 18 months of age, labels play the role of identifying novel kind members, which could be expected to share common generic properties.

In Experiment 4, we move on to further explore the mechanism that warrants ostensively presented information as attributable to kinds.

3.5 Experiment 4

This experiment had three aims. First, we wanted to replicate the results of Experiment 2, which supported the NG account over the IG account of how infants acquire generic knowledge via communication. Second, we intended to test whether the fact that the counterexample object had the same color as (and hence it looked identical to) the demo object, while the test object had a different color, contributed to the pattern of results in Experiment 2. Third, and most importantly, we added a further test to the procedure to explore a counter-intuitive hypothesis derived from the NG account. This hypothesis, which we detail below, came from the recognition that the IG and NG accounts of learning generic knowledge predict not only different responses to counterexamples but also potentially different ways of representing the demo object.

In inductive learning (IG), the learner accumulates evidence about individual exemplars and uses these data to generate expectations about further ones. By creating a summary representation of this evidence as generic knowledge, the learner can discard the evidence about particular exemplars. However, during the learning process, it is beneficial to store evidence about recent exemplars to allow re-evaluating the currently entertained hypotheses (in computational terms, the ‘model’) in the light of further evidence (Nagy & Orban, 2017). In our paradigm, when infants are confronted with negative evidence from the

counterexample and the test object, they may not only discard the hypothesis that the property in question was generic to the kind but could also generate the new hypothesis that this property was idiosyncratic to the demo object. Crucially, they could only do so if they stored this evidence, i.e., if they encoded the demo toy as ‘the object’ that had the property of lighting up. Thus, efficient use of inductive learning procedure predicts that infants would remember which object provided them with positive evidence of the property in question.

In contrast, in the account that attributes infants’ learning from communicative demonstrations to interpreting these demonstrations as expressing generic knowledge (NG), the property displayed by the demo object is not special to it. In such a demonstration, the demo object conveniently stands for its own kind, and whatever is expressed about it is bound to the kind as a whole, rather than to the specific object at hand. In other words, during the demonstration, this object primarily acts as a symbol for its kind, and not merely as an object about which something is to be learnt (Csibra & Shamsudheen, 2015). Thus, this account predicts that, having collected experience about all three objects (demo, counterexample, test), infants in the communicative condition would not necessarily remember which one displayed the property that they have learned to apply to the whole kind. This prediction is consistent with the observation that older children show decreased recall of individual exemplars after having learned conceptual or generic (as opposed to non-generic) information about them (Legare & Lombrozo, 2014; Walker et al., 2014). Furthermore, despite the fact that 3- to 4-year-olds’ memory is better for generalizable than non-generalizable properties, their memory is worse for the specific exemplars about which they have learned generalizable than non-generalizable properties (Riggs, Kalish, & Alibali, 2014a; 2014b).

In this experiment, we tested these predictions. On the basis of the NG account, we hypothesized that, after ostensive demonstration, if given a chance to choose which one to explore, infants would not privilege any one kind member over the others, because they would expect all objects to be equivalent in their generic properties. In contrast, if infants were encoding the demonstration as evidence about a particular exemplar, they could be expected to think that the demo object was unique in possessing the demonstrated property after having failed to elicit it from the other two objects. In this case, infants are expected to prefer the demo toy over the others. More specifically, we hypothesized that, if infants were to be given back all the three objects simultaneously after having inspected them separately, those who receive ostensive demonstration would choose randomly which object to explore, while those who receive non-ostensive presentation would prefer the specific exemplar they have encoded as possessing the novel property (i.e., the demo object).

3.5.1 Methods

Experiment 4 followed the procedure of Experiment 2 faithfully, with two additions. First, unlike in the previous experiments, we used objects that differed in color from each other, so that infants could identify these objects distinctly. Second, at the end of the test phase, the infants were offered a choice among the three objects, to test which object they preferred to explore (choice phase).

3.5.1.1 Participants

Thirty-two 18-month-old infants (mean age = 18.07 months, range: 17.5 to 18.5 months) from native Hungarian speaking families were included in the final sample (16 in both the Ostensive and the Non-Ostensive condition). Sixteen further infants were excluded: 14 infants because of failing to elicit the effect from the demo object, and 2 infants because of experimenter error.

3.5.1.2 Materials

A set of four Lego lamps, the same kind as in Experiments 1 to 3, was used. The set had one active object, used as the demo object, and another inert object of the same color as the demo (the dummy). Two additional inert objects played the roles of the counterexample and the test object. These objects differed in color from the demo object and from each other.

3.5.1.3 Procedure

The labeling, demonstration, and test phases were the same as in Experiment 2. At the end of the test phase, the infants were distracted for 10 seconds by another experimenter, who walked into the test room, making them look away from E1 who sat across the table. During this distraction, E1 changed the demo object for an identical looking but functionally disabled dummy object. The infants were then turned back towards E1, and the choice phase started.

During the choice phase, E1 slid the three objects (dummy, counterexample, and test object) from her end to the infant's end of the table, giving the infant enough time to see all the objects before touching them. The infants were then allowed to explore the objects for one minute.

3.5.1.4 Coding and Reliability

The test phase was coded in the same way as in Experiments 1 to 3. Inter-coder agreement was tested using intra-class correlation coefficient tests and was generally high (ICC ranging from .990 to 1.000).

During the choice phase, we measured preference in two different ways: by first touch, and by the number of attempts to make any of the three objects work. Touching or operating the dummy was taken to indicate preference for the demo object it replaced. When measuring first touch, if the infant touched two objects simultaneously (4 infants in the Ostensive condition, and 1 infant in the Non-Ostensive condition), 0.5 choice was coded for both objects. Inter-coder agreement was high for both measurements of the choice phase (ICC values ranging from .979 to 1.000).

3.5.2 Results

3.5.2.1 Test phase

A two-way mixed ANOVA with trial (demo object, counterexample, test object) as within-subject factor and communicative condition (Ostensive vs. Non-Ostensive) as between-subject factor revealed no significant main effects, but a significant interaction: $F(2,60) = 3.36, p = .041, \eta_p^2 = .101$ (Figure 3.4A). An independent samples t-test comparison of the number of attempts on the test object in the Ostensive and Non-Ostensive conditions revealed a significant difference ($t(30) = 2.21, p = .035$), with the number of attempts higher in Ostensive condition ($M = 5.8, SD = 3.5$) than in the Non-Ostensive condition ($M = 3.3, SD = 2.8$). No significant difference was found between the two groups in the number of attempts they spent on the counterexample. The difference in the number of attempts on the test object between the two groups was driven by a significant drop from the counterexample ($M = 5.5, SD = 2.96$) to the test object in the Non-Ostensive condition: $t(15) = 2.33, p = .035$. Such a difference was absent in the Ostensive condition ($t(15) = 0.86, p = .403$), which produced a similar number of attempts on the counterexample ($M = 5.1, SD = 2.7$) and on the test object. These results replicated those of Experiment 2.

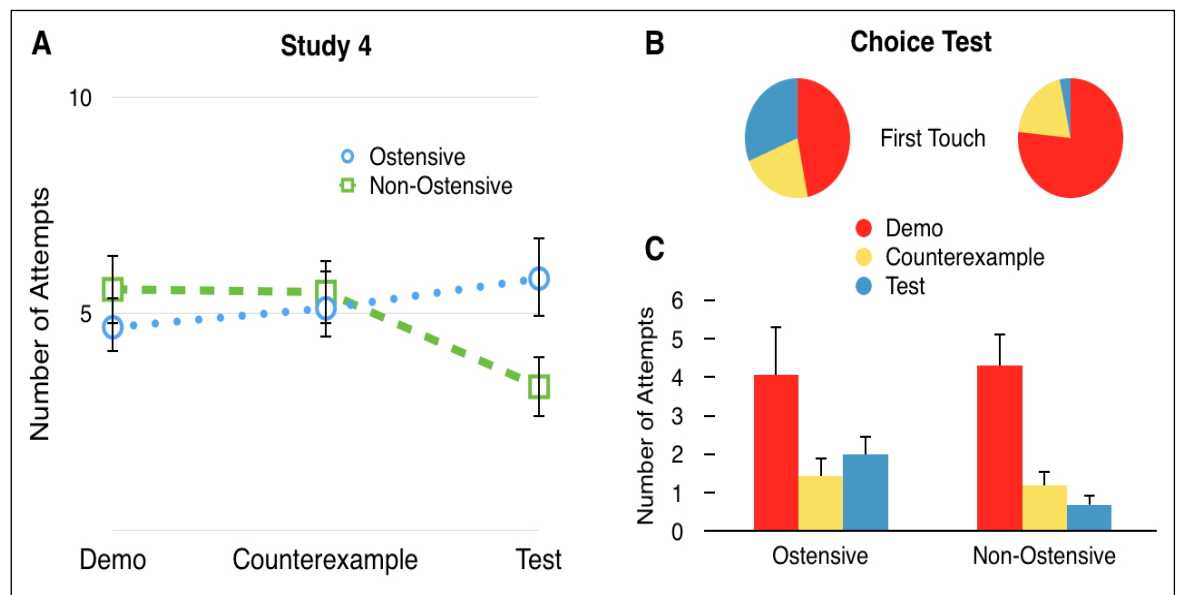


Figure 3.4. The mean number of attempts on each object in the test phase of Experiment 4 as a function of condition **(A)**. The right side of the figure depicts the proportion of first touches **(B)** and the number of attempts **(C)** on each object in the choice phase of Experiment 4. Error bars indicate standard error of the mean.

3.5.2.2 Choice phase

We analyzed first touches and number of attempts separately.

First touch. In the Non-Ostensive condition, 11 infants chose the demo object, 3 infants chose the counterexample, one infant chose both the demo and the test object, and one infant refused to make a choice. Converting these values for preference scores in percentages, 76.7% of infants (11.5 out of 15) preferred the demo object, 20.0% (3 out of 15) preferred the counterexample, and 3.3% (0.5 out of 15) preferred the test object (Figure 3.4B). These proportions are significantly different from equal preference by a goodness of fit test: $\chi^2(2) = 13.3, p = .001$. In the Ostensive condition, 6 infants chose the demo object, 3 infants chose the counterexample, 3 infants chose the test object, 3 infants chose both the demo and the test objects, and one infant chose both the counterexample and the test object. In terms of preference values, 46.9% (7.5 out of 16) preferred the demo object, 21.9% (3.5 out of 16) preferred the counterexample, and 31.2% (5 out of 16) preferred the test object (Figure 3.4B). These proportions are statistically not different from equal preference: $\chi^2(2) = 1.53, p = .465$. We also contrasted the choices of infants by calculating Bayes factors between two hypothetical multinomial distributions: that the choices came from a uniform distribution (1/3, 1/3, 1/3) or from a skewed distribution towards the demo object (.8, .1, .1). In the Non-Ostensive condition, the choices were 295.8 times more likely to come from the skewed

distribution, while in the Ostensive condition they were 46.2 times more likely to come from the uniform distribution. Thus, while the infants tended to reach first towards the demo object in the Non-Ostensive Condition, no such preference was expressed in the Ostensive condition.

Number of attempts. The infants made the most attempts on the demo object in both conditions (note that all objects were inert in the choice phase). In the Non-Ostensive condition, they pressed the demo object 4.3 times, the counterexample 1.2 times and the test object 0.7 times on average. In the Ostensive condition, the corresponding values were 4.1, 1.4, and 2.0, respectively (Figure 3.4C). A two-way mixed ANOVA with object (demo, counterexample, test) as within-subject factor and communicative condition (Ostensive vs. Non-Ostensive) as between-subject factor revealed only a significant main effect of object $F(2,60) = 16.35, p = .001, \eta_p^2 = .353$, indicating a preference for the demo object.

3.5.3 Discussion

The results of Experiment 4 replicated those of Experiment 2: attempts to elicit the response from the test object dropped only in the Non-Ostensive, but not in the Ostensive condition, despite that fact that the counterexample was explored with similar persistence in both conditions. Given that the three objects were marked as members of the same kind in both conditions, the vulnerability to the counterexample displayed by the infants in the Non-Ostensive condition indicates that they were unsure about the property being shared by all the kind members, while the negative evidence from the counterexample had no effect on their subsequent attempts on test object in the Ostensive condition. Thus, the results from both Experiment 2 and Experiment 4 show that, in ostensive contexts, information conveyed about even a single exemplar is represented by 18-month-olds as generic information about its kind, and that this outcome does not depend on hypothesis testing further exemplars.

The second test included in Experiment 4 probed the hypothesis that only the infants in the Non-Ostensive condition would show a preference for the demo object. This prediction was only partially confirmed. The infants who had received non-ostensive demonstration were significantly above chance in touching the demonstration object first, while the behavior of the infants in the ostensive condition was closer to random selection in this measure. This result supported our prediction that the infants in the Ostensive condition encoded the demonstrated property with reference to the object kind and expected the demo object to be equivalent with other objects of its kind. This is a counter-intuitive finding, uniquely predicted by our proposal. After all, the infants in both conditions had seen the experimenter elicit the property from the demo object three times, and themselves experienced positive results only

with the demo object. The fact that the experimenter addressed them during the demonstration made them *less*, and not *more*, likely to encode, and subsequently choose first, the object used during this demonstration. This is an indication that what they learned from this demonstration was not simply a property of the particular object they observed.

Nevertheless, while the infants could freely explore the three inert objects, they tended to make more attempts on the demo object than on the other two objects in both conditions. This suggests that, contrary to our prediction, the infants could identify the source of their newly acquired knowledge even in the Ostensive condition, and, at least when neither of the other two objects met their expectations, they resorted to this source in selecting actions that would have most likely produced an effect. This result diverges from the patterns of findings with older children (e.g., Riggs et al., 2014a). This discrepancy might be due to the fact that, unlike other tasks, our procedure gave the infants ample opportunities to compare and memorize the perceptual features of the specific exemplars, as they were left on the table after they had explored them. While this result suggests that the infants had more confidence in their hope of eliciting the novel property from the object they believed was the demo toy in both conditions, in the Ostensive condition they tended to rely on this memory only after they failed to achieve the desired effect from a randomly chosen toy.

3.6 General Discussion

The experiments in this paper set out to investigate the mechanisms by which nonverbal communication about particular objects facilitates the learning of generic knowledge in infants. We contrasted two potential candidate mechanisms, namely, that (1) communicative demonstration simply modulates ordinary inductive generalization (IG) processes, or that (2) communicative demonstration is interpreted by infants as expressing generic knowledge directly as nonverbal generics (NG). Both learning mechanisms can account for many phenomena of generalization in early childhood. Nevertheless, we identified a signature phenomenon that could discriminate between them: the knowledge acquired by these mechanisms should respond in different ways to counterexamples. Counterevidence should decrease the strength of inductively generalized (IG) knowledge, while such evidence should be discarded as non-representative anomaly when evaluating its relevance to knowledge acquired via NG.

The results of Experiments 2 and 4 confirmed the predictions of the NG account better than those of the IG account. In response to counterevidence, the infants in both experiments dropped their expectation of generalizability of the non-ostensively demonstrated object property but persisted in trying to elicit the ostensively demonstrated property from the

test object (Prediction 2). This difference emerged between the presentation conditions even if the infants were equally eager to make the counterexample work after ostensive and non-ostensive demonstrations (Prediction 1). Thus, our findings are compatible with the proposal that learning and generalization during our task were governed by different mechanisms (NG and IG) depending on whether the initial information about the property of an object was acquired from communication (NG) or from observation (IG).

A potential objection to this conclusion is that the apparent counterevidence-resistant learning we found in the ostensive conditions might have been due (not to generic interpretation of the demonstration but) to modulation of ordinary inductive learning by the communicative demonstration, which might induce very strong confidence in the generalizability of the demonstrated property. If, for the infants, the ostensive demonstration was worth as much as, say, 10 instances of observational evidence, the single counterexample would have exerted only a small effect on it (1 negative observation against 10 positive ones), which would not be comparable to its effect in the Non-Ostensive condition (1 negative observation against 1 positive one). Such a small effect may not be detectable as a drop in the number of attempts to operate the test toy in the Ostensive condition and this way our results would be compatible with the IG account. However, the infants' reaction to the counterexample object speaks against this interpretation of the results. Contrary to Prediction 1, drawn from the IG account, we found no evidence of greater attempts on the counterexample object in the Ostensive than in the Non-Ostensive condition in any of the experiments. This suggests that the difference between the conditions, which was manifest as persistence on the test object only after experiencing the counterexample, was due to not a quantitative but a qualitative difference in how the communicatively conveyed information is encoded and consequently how the counterexample is assimilated into the existing knowledge about the kind.

We propose that learning from nonverbal communicative demonstration is akin to interpreting a generic sentence (e.g., "Knives are sharp") that states something about a kind of entity (Carlson & Pelletier, 1995; Gelman, 2004; Leslie, 2008; Prasada, 2000). Such sentences do not assert anything about particular individuals but specify characteristic core properties of the kind as a whole. Similarly, a nonverbal communicative demonstration on a single object could be interpreted as expressing a characteristic property of the kind it represents. Because generic sentences and nonverbal ostensive demonstrations express characteristic properties of a kind, these properties are expected to apply to kind members, allowing for quasi-deductive generalization. But since verbal and nonverbal generics are not about individuals or sets of individuals, they also allow exceptions: kind members that do not display the property (e.g.,

blunt knives) do not invalidate the assertion (Cimpian, Brandone, & Gelman, 2010; Gelman & Bloom, 2007; Leslie, 2008). This is why the infants in the Ostensive conditions of our experiments were not discouraged by the counterexamples but upheld their belief that the property displayed by the demo object was generic to the kind as a whole.

One precondition for this kind of learning is that the demonstration object is to be treated as an ad-hoc symbol standing for its kind: just like “knives” in “Knives are sharp” refers not to a particular set of knives but to the object kind ‘knives’ as a whole, the demo object in a nonverbal demonstration is exploited to convey a statement about the kind it belongs to (cf. Csibra & Shamsudheen, 2015). The choice test in Experiment 4 partly confirmed this interpretation: though the infants made the most attempts on the object they believed was the demo object, their first touch in the Ostensive condition was equally distributed among the options, as if they thought that any member of this kind of object should display the demonstrated property.

In order to be useful for learning and generalization, NG mechanisms (just like IG mechanisms) should also satisfy another condition: learners have to be able to assess the scope of the acquired knowledge by identifying members of the kind they have learned about. Our findings suggest that, while shape similarity can support inductive hypotheses, it is not sufficient for inferring shared kind membership for 18-month-olds (at least when the objects display different functional properties or lack thereof). However, as Experiments 2 & 4 demonstrated, shared labels serve this function very well. At first sight, it may seem to be a self-contradictory proposal that a nonverbal learning mechanism works only in the presence of linguistic labels. However, according to the NG proposal, labels are not necessary for learning of generic knowledge – what may be necessary for the expression of this knowledge is sufficient information about shared kind membership. In our study, labels fulfilled this function, but other kind identifiers, such as shared function could also be exploited for this purpose. In addition, we found in Experiment 3 that labeling alone, when it did not carry information about shared kind membership among potential exemplars, did not lead to knowledge resistant to counterevidence. Butler and Tomasello (2016) also found that 2-year-olds required explicit labeling of all objects in order to extend communicatively acquired knowledge to them. Object labels may play additional functions later in development, but their initial contribution seems to be the identification of “which entities belong to a kind” (Gelman, 2004, p. 476). Note also that such strong reliance on labels in early learning from communication may be incompatible with the view that supervised category learning emerges only later in development (Sloutsky, 2010).

Our findings is evidence that the acquisition of generic knowledge does not require either inductive generalization or linguistic expressions. As the first study of addressing this question, our study has clear limitations. It is possible that specific features of our adopted procedure contributed to the results. For example, we used novel, unfamiliar objects in our study – a choice that itself could also raise the expectation of potential to acquire novel knowledge. In other words, a demonstration of a novel dispositional property of a familiar object may not result in encoding of the said property as generic, whether or not the demonstration is ostensive. Infants may also have intuitions about which properties are, and are not, likely to be generic. For example, functional properties, such as the one we adopted in our study, would be more amenable to be learned as a generic property than episodic attributes, such as wetness. If so, then perhaps NG mechanisms would be restricted to demonstrations of the former type of (i.e., ‘projectible’) properties (see Goodman, 1983). These questions await further investigations.

Nevertheless, our findings already indicate that what prepares human infants for exploiting an evolutionarily new learning mechanism may not be language *per se*, but sensitivity to, and expectations about, ostensive communication. This learning mechanism provides a shortcut to the acquisition of generic knowledge, saving infants from computationally costly inductive learning when a benevolent adult is willing to provide it for free (cf. Csibra & Gergely, 2009). Such knowledge is ‘free,’ but it comes with a hidden price. Beyond well-known demonstrations that learning from others’ communication makes children prone to adopt unnecessary actions (Horner & Whiten, 2005; Király et al., 2013; Lyons, Young, & Keil, 2007), and to miss valuable opportunities to discover new knowledge (e.g., Bonawitz et al., 2011; Muentener & Schulz, 2012), it may also prompt children to dismiss evidence that contradicts what they have already learned (see also Hernik & Csibra, 2015). This early manifestation of ‘confirmation bias’ is thus both a consequence and a signature of learning generic knowledge from verbal or nonverbal communication (Csibra & Shamsudheen, 2015).

Chapter 4

The role of ostensive reference in mapping labels to objects

4.1 Introduction

In Chapter 2 we provided evidence that ostensive reference to objects can trigger encoding the referents in terms of their kind. The objects explored in Chapter 2 belonged to kinds familiar to the infants. Yet, despite the familiarity and potentially existing kind representations, familiar objects are not spontaneously encoded in terms of the kinds they represent (cf. Xu & Carey, 1996). The fact that prompts are required for activating kind-based encoding of familiar kind members in terms of their existing kind representations indicates that for young infants thinking in terms of kinds when engaging perceptually with individual exemplars is not an automatic process. For example, in a task similar to kind-based individuation described in Chapter 2, where infants' ability to individuate objects was based on accessing kind information, 10-month-olds succeeded only when the distinct functions of unfamiliar objects were ostensively demonstrated, allowing them to recognize these objects as members different kinds of artifacts characterized by different functions (Futo et al., 2010). On the other hand, the infants failed at kind-based individuation, when distinct functions that could potentially define the objects as different kinds were presented without ostensive reference. This indicates that without ostensive reference the properties failed to be linked as kind functions to the objects' kind and thus failed to utilize the distinct functions to infer the presence of two distinct kinds (Futo et al., 2010).

Studies with older infants also show similar patterns of results. Children do not strongly map functional properties to an object's kind unless the function is demonstrated within an ostensive referential context. When an object's function was demonstrated in an ostensive referential context (rather than in a non-ostensive context), both 13-month-old infants (Hernik & Csibra, 2015) and 2-year-old children (Butler & Tomasello, 2016) showed resilience in the face of counterevidence that would have indicated that the demonstrated function might not be a consistent feature of the object kind (see also Butler & Markman, 2012, for similar results with 4- to 5-year-old children). These results indicate that when a function is observed to be exhibited by a specific object, infants and even older children fail to map the function to the object's kind unless they are presented to them in an ostensive referential context. These studies suggest that ostensive reference facilitates linking an object's potentially kind relevant property, such as function, to its kind and thus unlocking the object's potential to represent its kind.

On the other hand, labels have been proposed to be unique and privileged in their ability to elicit kind representation (Waxman, 1999; Lupyan, 2016; Xu, 2002). Count nouns have been proposed to be special terms that refer not to specific exemplars but to conceptual

categories or kinds that can be expected to have common properties (Waxman & Gelman, 2009), perhaps stemming from a common deeper essence or character (Gelman, 2003). Thus, it is not surprising that current evidence indicates that, from as early as 6 to 9 months of age, infants comprehend familiar nouns that refer to kinds rather than just the specific exemplars that they have observed being labeled (Parise & Csibra, 2012; Tincoff & Jusczyk, 2012; Bergelson & Swingley, 2012; Bergelson & Aslin, 2017). Although these studies were taken as indicating that young infants are able to link words to kinds, they had only tested comprehension for words and kinds that were highly familiar to the infants across many different situations. In this case, it is possible that the infants did not comprehend the noun-kind link, but merely learned to associate the acoustic feature (the word) that co-occurred with the shared visual features of the multiple different exemplars over numerous occasions (Plunkett, 1997; Sloutsky, 2010; Smith & Yu, 2007; Landau, Smith, & Jones, 1998; Yuvrovsky et al., 2012). According to some proponents of the associationist view, children are incapable of appreciating the symbolic link of words to kinds until they are around 7 years of age. They suggest that before this age object labels are merely recurring acoustic features of objects, which increase the overall similarity between the objects and allow them to be clubbed together, associated with the same label (Badger & Shapiro, 2012; Sloutsky et al., 2015; Sloutsky, Kloos, & Fisher, 2007). The proposals that infants map labels only to the immediately perceptible object and its features at the time of labeling are well aligned the view that it is impossible to have perceptual experience of kinds, and hence kind based representations and mappings cannot be formed without multiple cross-situational experiences and a protracted development period (Sloutsky, 2010).

However, empirical evidence goes against this purely perceptual associative understanding, according to which object labels are first encoded only to be later imbued with conceptual mappings. Infants appear to fast map labels onto concepts even with minimal exposure to both the label and its referents (Yin & Csibra, 2015; Macnamara, 1982; Gelman, & Taylor 1984; Waxman & Markow, 1995; Soja, et al., 1991; Waxman 1999; Waxman & Gelman 1986; Waxman & Booth, 2003; Booth & Waxman, 2009; Booth, Waxman, & Huang 2005; see for a review: Waxman & Leddon, 2011). Already at 9 months of age infants have a strong implicit assumption that words refer to kinds without having multiple exposures to the specific word-object pairing. For instance, Dewar and Xu (2007) showed that after an experimenter looked into a box and called out two distinct labels, "I see a zav! I see a dak!", infants expected the box to contain two different kinds of objects. This was shown by the fact that they looked longer when two identical objects, instead of two different looking objects, were pulled out of the box, indicating a violation of their expectation of two distinct object

kinds (a common kind membership evident by a shared appearance), presumably stemming from their assumption that the two distinct words indicated two distinct objects kinds. On the other hand, when they heard the experimenter utter twice the same label, "I see a zav! I see a zav!", and two different looking objects were pulled out, infants indicated a violation of their expectation by looking longer at the objects compared to when two identical looking objects were pulled out. Infants' behavior in this study indicates that when they heard a single noun repeated twice, they expected two objects of a single kind and when they heard two distinct nouns, they expected two different kinds of objects evident from their difference in appearance (Dewar & Xu, 2007). Further evidence that infants expect words to refer to kinds come from word extension studies. When presented with demonstrative labeling of a single exemplar, infants expect the novel label to refer not only to the specific object that has been labeled but also extend the label to other exemplars that match the initially labeled exemplar on visual features, such as shape, or conceptual but non-obvious properties, such as function (Gelman & Taylor, 1984; Golinkoff et.al., 1992; Graham et al., 2004).

Further strengthening the evidence that infants expect words to refer to kinds are studies that show that they expect common objects with shared labels to share common non-obvious properties, even when the objects are not perceptually similar. For instance, 10-month-old infants who were shown a pair of objects labeled with a common label expected the objects to make the same sound, while expecting two different sounds from a pair of objects labeled with two distinct nouns. This effect of labels in indicating that the objects are of a kind, sharing common non-obvious properties, was observed regardless of whether the paired objects had a common shape or not (Dewar & Xu, 2009; see also Waxman & Braun, 2005). Furthermore, studies with older infants indicate that they interpret shared labels to be grounds for expecting shared kind membership with shared common non-obvious properties. For instance, in a series of studies with infants ranging in age from 13 to 22 months, Graham and colleagues have shown that infants extend non-obvious properties to other objects that are dissimilar or have low similarity in shape when they are labeled with the same name (Graham et al., 2004). Joshi (2005) also found similar results with 18-month-olds. Crucially, in all of these studies, although labeling and exposure to the objects were minimal, single episode instances, young infants demonstrated that they expected words to refer to the kind of the object labeled and extended the label and other properties of the labeled object to novel exemplars of the kind that were not present at the time of labeling.

4.1.1 How Do Infants Know that Object Labels Refer to Kinds?

Given that kinds are not concrete entities that can be presented physically, which would allow infants to link an object's label directly to the kind, infants' ability to promptly link object labels to kinds is a puzzle. After all, words could also be proper names that refer to specific objects. How do they, on observing an act of labeling, know that the word applies to the object's kind and not the object itself? Attempting to explain the direct link words have to semantic and abstract conceptual representations of kind, various researchers have suggested that there are innate cognitive constraints or default assumptions that act as guide posts that bestow infants with a default expectation that words refer to kinds. The most prominent among these assumptions is the basic-level category bias (or taxonomic bias), an inherent bias to encode object labels as symbolic references to novel basic level categories rather than as names of specific novel objects even when the label is explicitly applied to specific objects (Macnamara, 1982; Markman, 1989; Nelson 1973; Golinkoff et al. 1992; Mervis, Golinkoff, & Bertrand, 1994; Markman & Hutchinson, 1984; Markman 1991).

Yet, others have suggested that it is a feature of verbalized object labels themselves that they induce kind-based representation of the labeled objects (Xu, 2007, 2002, 2012; Waxman & Markow, 1995). One such account proposes that words invite infants to focus on the commonalities among objects (i.e., their perceptual and beyond-perceptual similarities), and license them to assume that objects labeled with the same names share conceptual, non-obvious features that tie them together as kind members. According to this account, infants have an inherent bias that words act as "invitations to form categories" (Waxman, 1999). In agreement with this account, infants are proposed to spontaneously take words to be "essence placeholders" that map onto as yet undelineated kinds (Gelman, 2003; Xu, 2002, 2007; Carey, 2009). Or as Gelman and Brandone (2010) put it, "the process of fast-mapping object terms involves creating a placeholder meaning 'a kind of X'".

These accounts presuppose that infants have latent knowledge that the world is not made up of a random collection of individuals but of exemplars that belong to categories and kinds that share some common defining features. Or in other words, infants come equipped with a pre-existing 'kind notion' that goes beyond conceiving entities as individuals but assumes that every entity to belong to a kind (Gelman & Brandone, 2010). Such a 'kind notion' would then allow infants to fast-map the label applied in a specific episode to a specific object to its kind, and then expect that other exemplars of the kind also fall under the same label.

On the one hand, the results reviewed above and the theories that attempt to explain them suggest that infants spontaneously encode object labels as count nouns that refer to

kinds. However, a couple of studies indicate that this may not be entirely correct. The assumption that words spontaneously refer to kinds may come from the fact that all of these studies had a confound: the labeling acts were always also ostensive referential acts. In studies where a dissociation between the labeling act and ostensive reference was made, infants failed to link the words to object categories. For instance, Campbell and Namy (2003) presented 13- and 18-month-old infants with object labels in two conditions, referential and non-referential. In the referential condition an object was labeled in an ostensive referential fashion, i.e, the experimenter engaged with the infant in a deictic interaction while labeling the object: “Look at what you have! (Label), That’s what we call that one. Do you see what you have there? (label) That’s what that is! Do you like that one? (label)”. In the non-referential condition, the experimenter engaged the infant in a similar ostensive interaction, but the object label was dissociated from the ostensive reference, because it was produced by a baby monitor and not by the experimenter. In a subsequent forced-choice test, both 13- and 18-month-olds, but only those who participated in the referential condition, showed evidence of having learned that the label referred to object kind: they successfully mapped the word not only to the initially labeled objects but also to novel exemplars that differed in color. But even more telling was the fact that when they were presented embedded in ostensive referential packaging, infants spontaneously fast-mapped not just words but also non-verbal, both acoustic and non-acoustic stimuli to object categories (Namy & Waxman, 1998; Campbell & Namy, 2003; Ferguson & Waxman, 2016; Graham & Kilbreath, 2007). We take these studies to indicate that when a label is shorn of its ubiquitously associated ostensive reference, it loses its power to be directly linked to a kind, while even non-words, when couched in ostensive referential packaging and used to ‘label’ an object, are expected to refer not just to the ‘labeled’ objects but also to other kind members.

Another study showing similar results with 16-month-olds further underlines the role of ostensive reference in mapping words onto objects kinds (Keates & Graham, 2008). One could claim that in the above-mentioned studies the infants were merely associating the labels to common visual features, the novel exemplars shared with the previously labeled objects, and ostensive reference perhaps worked as an attentional highlighter of the common features. Keates & Graham (2008; see also Graham & Kilbreath, 2007, for similar results with 14- and 22-month-olds) went one step further and provided evidence that infants indeed map labels to kinds by showing that objects labeled the same are also expected to possess common non-obvious properties, even when differing in visual features. But, what is relevant to us here is that the infants only used the same label as indicating a common kind when the objects were labeled by the same source that had ostensively referred to the object. In the study, all infants

were first introduced to an object and its novel function in an ostensive demonstration. Subsequently, in the ostensive referential condition, the demonstration object was labeled in an ostensive referential manner (“This is a blick”) by the experimenter, while in the non-ostensive referential condition the object was labeled by a recorded voice. The infants were tested on two test objects, one that was similar in shape to the demonstration object and another one that had a different shape. The test objects were presented to the infant one after another, but before the exploration period both were also labeled with the same label as the demonstration object, either by the experimenter (in the ostensive referential condition) or by the recorded voice (in the non-ostensive condition). After labeling, the infant explored both test objects and the number of times she acted on each to produce the demonstrated function was noted. Only infants who received the ostensive referential labeling, expected the objects labeled the same way as the demonstration object to belong to a common kind, disregarding differences in perceptual features. Only these infants expected the shape-different test object to possess the demonstration object’s property. In contrast, when the labeling was non-ostensive, infants extended the demonstrated property by shape similarity, expecting the property from the shape-similar test object and disregarding the common label of the demo and test object (Keates & Graham, 2008). The studies reviewed here suggest that infants fast-map words to kinds only when the labeling comes together with ostensive reference to the labeled object, suggesting that ostensive reference plays an imperative role in connecting words to object kinds.

4.1.2 What is the Role of Ostensive Reference?

When an object is perceived it stands as itself, any predicate expressed for it is logically bound to itself. In order to allow the predicate to be bound to the object’s kind and not to the object, the object needs to represent its kind or, in other words, be encoded as beyond itself and as a symbol representing its kind. In Chapter 2 we provided evidence that ostensive reference can trigger kind-based encoding of the exemplars of familiar kinds in 9-month-old infants. In studies with infants, labeling is typically packaged together with ostensive reference to the labeled object, and this has led to the idea that labels are unique in being always directly mapped as a generic feature of the kind. Contrary to this assumption, we propose that labels are linked to kinds because, just as with familiar objects, ostensive reference induces kind-based representation of exemplars of unfamiliar object kinds, with the referent object standing as a symbol for the yet unknown kind. This then allows an ostensively communicated predicate, for example a label, to be construed as a kind label rather than as the proper name of the object.

This proposal is similar to the idea that words stand as symbolic ‘essence placeholders’, allowing specific objects to be represented in terms of their kind (Xu, 2002). Here, we propose that ostensive reference creates a placeholder for the object kind that the ostensively referred object belongs to, which in turn allows the label to be linked to the kind placeholder. Importantly, this proposal would explain three crucial puzzles:

- 1) How do words get mapped to objects kinds even after a single instance of ostensive labeling, well before infants are capable of identifying the syntactic markers of proper vs. count nouns?
- 2) Why, despite the privileged status that some have claimed words alone enjoy, do gestures and even non-linguistic acoustic stimuli acquire word-like powers of defining categories (Fulkerson & Waxman, 2007) and identifying novel category members (Graham & Kilbreath, 2007; Namy & Campbell, 2003)?
- 3) Why do words, when presented isolated from ostensive referential packaging, fail to induce infants to take commonly labeled objects as fellow kind members (Fulkerson, Shull, & Haaf, 2002; Keates & Graham, 2008).

Note that our proposal is not that ostensive reference can replace words, or that it is as flexible as words are in their symbolic capacity to refer to even absent objects, without ever instantiating even a single instance of the kind. Our claim is not that, like labels, ostensive reference itself can stand in as a placeholder for a kind. Instead, we propose that ostensive reference is the glue that binds a predicate to the kind rather than to the perceptible individual that is being directly referred to. Our proposal is that ostensive reference to an object triggers its kind-based representation. While in the case of familiar kinds, ostensive reference enables the object to be identified as ‘belonging to kind K’ (Chapter 2), in the case of unfamiliar kinds, it opens a placeholder for a new kind, with the referent conceptualized as the symbolic instantiation of the kind.

4.1.3 The Current Study

In the current study, we tested the proposal that ostensive reference triggers kind-based representations of unfamiliar objects. To this aim, we manipulated the availability of ostensive reference to an unfamiliar object before it was labeled, and assessed whether the label was mapped onto it. Since previous studies have shown that by 22 months of age infants have come to privilege words as kind markers (Graham & Kilbreath, 2007) and that by 2 years of age children map labels to kinds without ostensive reference (Jaswal & Markman, 2001),

while at 16 months they still consider many other forms of reference couched in ostensive referential contexts as potentially referring expressions, we chose to study 18-month-olds.

In one group, 18-month-old infants were presented with a video of an adult (X) engaging the infant in an ostensive-referential introduction to a novel unfamiliar object (O1). In order to dissociate this ostensive referential introduction from the ostensive nature of the labeling itself, the experimenter placed the object into an opaque bucket before proceeding to look into the bucket and labeling it using a novel word (e.g., “A pota”). After labeling, X left and another adult (Y) came in and took out a different object (O2) from inside the bucket. Our interest here was which of the two objects the infant would attach the label to: to the initially ostensively introduced O1, or to O2 which was made visible following the labeling. Based on our proposal that ostensive reference opens a kind placeholder, we hypothesized that the label would be attached to this novel kind (represented by O1), despite the fact that, if going by pure association, infants could attach the label to O2, presented immediately following labeling. For a second group of 18-month-olds, the experiment was identical except that the initial introduction of the novel object was non-ostensive. Here we expected that the infants would attach the label to O2, given that O2 was presented immediately following the labeling. At test, the infants were first presented with O1 and O2, and then they were administered a word recognition test. They were asked either about the familiarized label (e.g., “where is the pota?”), or an untrained label (e.g., “where is the szemo?”). We expected that, when asked to find the referent for the familiarized label, infants who had received ostensive introduction to O1 would look longer at O1, and infants who had received non-ostensive introduction to O1, would look longer at O2. In comparison, when asked to find the referent for the untrained label, we predicted that infants would perform at chance.

4.2 Experiment

4.2.1 Methods

4.2.1.1 Participants

Thirty-two 18-month-old (mean age: 18 months 3 days; range: 17;15-18;15), full term, healthy, monolingual Hungarian infants participated in the study. Nine additional infants were tested but were not included in the final analysis because of failing to fulfill our inclusion criterion for looking time during the presentation (see Data Analysis below), and further 5 and 3 infants were excluded due to fussiness and experimental or technical error, respectively. Informed consent was obtained from all parents before the experiment commenced.

4.2.1.2 Apparatus

A TOBII T60XL eye tracker (Tobii, Danderyd, Sweden) was used to collect the infants' binocular gaze data. The stimuli were displayed on a 24-inch monitor (resolution = 1920 x 1200 pixels, sampling rate = 60 Hz) integrated with the eye-tracker. The audio stimuli were delivered through the loudspeakers built into the eye tracker. The experiment was administered using custom-built Matlab scripts, with the Psychophysics Toolbox (Brainard, 1997) for data presentation and Tobii Pro Analytics software development kit for data collection (<http://www.tobii.com/product-listing/tobii-pro-analytics-sdk/>).

4.2.1.3 Stimuli

Speech stimuli. Two pseudo-words consistent with Hungarian phonotactics were used as labels: *pota*, *szemo*. The words were embedded in minimal carrier phrases, as described below (see Design and Procedure). All speech was recorded by a female native speaker of Hungarian using adult-directed intonation.

Object stimuli. Two novel objects that differed from each other in color, size, and shape (1: a rounded purple & green object made from polystyrene; 2: a triangular yellow & orange object made from wood) were constructed specifically for the experiment to ensure their unfamiliarity and make them maximally visually distinct from each other. The objects were used in constructing the video stimuli, as described below.

4.2.1.4 Design and Procedure

The experiment was conducted in a dimly lit soundproof room. The infant was seated on their parent's lap, approximately 60 cm from the monitor. Parents wore opaque sunglasses to ensure that the eye tracker would not track their gaze. Parents were also instructed to avoid moving or interacting with the infants in any manner.

Before the task started, each infant watched a five-point calibration sequence. The calibration stimulus was a dynamic spiral that changed color and size as it was presented successively at the center and four corners of the monitor. The order in which the calibration stimuli appeared at the five points across the monitor was random. The calibration sequence was repeated until at least four points were successfully calibrated before the infants proceeded to the experiment.

The experiment consisted of an induction phase followed by a word-mapping test phase. In the **induction phase** the infants were presented with a pre-recorded video clip (61 s duration), edited with Final Cut Express 4.0. The video presented an adult (X), who explored an object and placed it inside an empty opaque container effectively occluding the object from

the infant. Then she looked into the bucket and uttered a label twice. X then left the room, while another adult (Y) came in and took out a different object from inside the container (the initial object apparently having undergone a featural transformation while inside the container).

Two groups of infants were tested. The design across groups differed only with respect to how the object was initially introduced to the infants. One group of infants received an ostensive induction phase where the experimenter introduced the object communicatively, directly addressing the viewer. The other group of infants received a non-ostensive induction phase, in which the experimenter merely examined the object without engaging in eye-contact or producing any other communicative gestures.

Immediately after the induction video was over, infants in both groups were administered a word-mapping test, identical across groups. The aim of this test was to determine whether they assigned a referent to the previously uttered label, and if they did so, whether the referent was the pre-change/initial object or the post-change/transformed object.

Induction phase. The induction phase had two parts: exposure and labeling. The two groups differed only in the exposure part, where for the ostensive group the object was introduced communicatively while the non-ostensive group received a non-communicative introduction to the object.

Exposure part. In the ostensive group, the induction video (Figure 4.1) started featuring an adult X, who sat with her attention on a table (covered with gray cloth) set against a black screen with the space around the screen visible. A red bucket and one of the novel objects were placed on the table. X looked up, smiled and waved to the infant saying, “Hi, look!” (“Szia, figyeli!”). She then looked down at the object, picked it up and held it up, presenting the object to the viewer. She then proceeded to inspect the object, intermittently establishing eye contact with the viewer, and then looked up and held up the object to the viewer again, such that a joint deictic reference was seemingly established between her and the viewer with regards to the object. She then looked down back at the table, stopped interacting, and placed the object back on the table.

In the non-ostensive group, the sequence and timing of the actions presented were the same as in the ostensive group. However, X did not look up or present any communicative gestures towards the viewer. Instead, she examined the object passively, seemingly self-absorbed. To match the actions and speech in the exposure part of the ostensive group, the experimenter made hand movements to tuck her hair behind her ears, cleared her throat and made interjections like ‘hmm...,’ while she examined the object. All following events were

identical for both the ostensive and non-ostensive groups. The object-exposure sequence took 25 seconds in both groups.

Labeling part. In labeling part of the induction phase immediately following the introductory phase, the experimenter was non-ostensive, refraining from making eye contact with, or other interactive gestures towards, the viewer. X picked up the bucket that was present on one side of the table and tapped it on the table twice in an angle that the viewer could see that it was empty (6 s). She then placed the bucket back on the table in front of her, picked up and placed the object into the bucket (4 s). She looked into the bucket and said in an adult-directed manner (i.e., without using infant-directed speech intonation), “A pota” (“Egy pota”), then paused and repeated the labeling ‘A pota’ again (10 s). X then got up and left the room, while another adult (Y) came in from the other side such that the infants could see one of them leaving and the other experimenter coming in at the same time (5 s). Y looked into the bucket (3 s), picked up an object from inside and placed the object on the table (4 s). Note that this object was different from the one that had been placed into the bucket before. She then tapped out the bucket twice on the table and held it such that the infant could see that there was no other object inside the container (3 s) and left the room with the bucket. The video ended 1 second after Y left the room. At the end of the induction phase, an attention getter was presented in the middle of the monitor, to reorient the infants’ attention to the center of before the the test phase began.

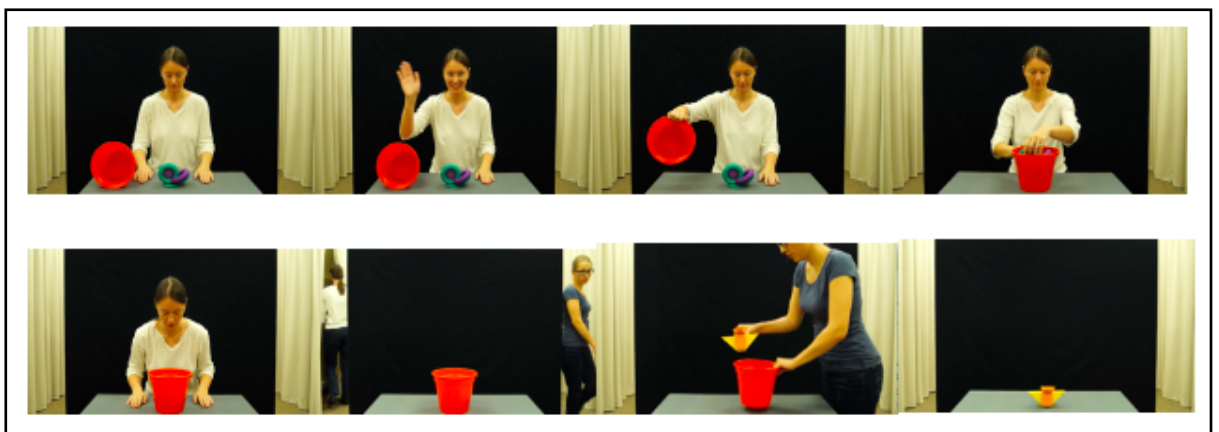


Figure 4.1. Illustrative frames from the Induction phase of the experiment.

Test phase. The test phase (Figure 4.2) was identical for both groups and consisted of 4 test trials, each composed of a baseline period, followed by a test question, and a post-naming measurement period.

Baseline period. After the attention getter was presented to orient the infant towards the center of the screen, the initial object and post-change object were presented on the opposite

sides of the screen (3 seconds). Then, a gaze-contingent attention getter appeared in the middle of the screen between the two objects to orient the infants towards the center of the screen away from either of the two objects.

Test question. Once the infant had fixated on the attention getter for 0.5 seconds, the test speech stimuli were delivered: “Look! Where is the LABEL?” (“Nézd csak, Hol van a LABEL?”) (2.4 s audio) was presented. Infants heard either the same label as during the induction phase (e.g., pota; trained-word condition) or a novel unfamiliar label (e.g., szemo; untrained-word condition).

Post-naming measurement period. At the offset of the test question, the attention getter disappeared, and the measurement period commenced. After a fixed interval, the label used in the test question was repeated alone without any carrier phrases (“pota/szemo”), and was repeated once more thus, after another fixed interval. The measurement periods lasted for a total duration of 5.5 seconds.

Animated attention getters were presented before the induction phase and before each test trial. The attention getters did not have a predetermined duration but were gaze contingent and remained on the monitor until the infant had fixated them for 0.5 s.

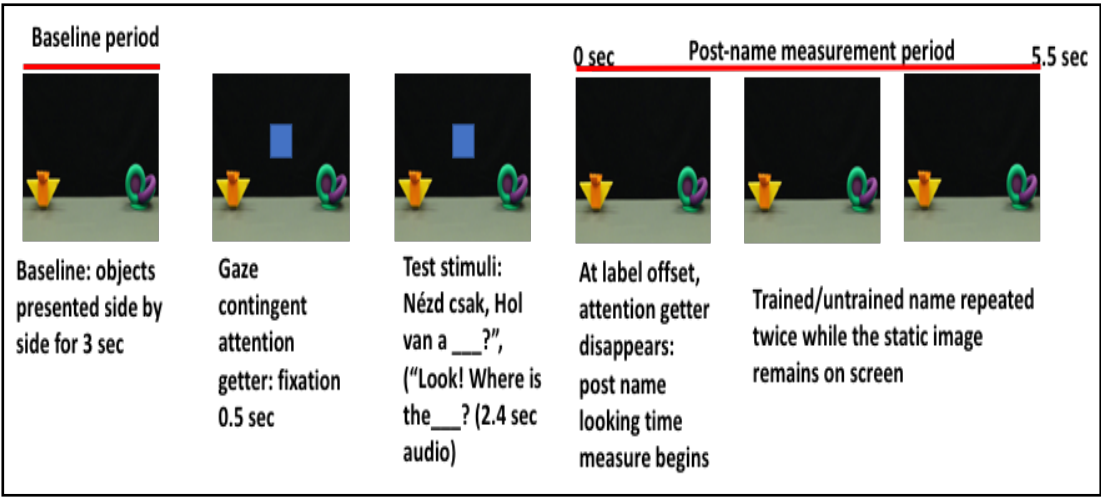


Figure 4.2. Schematic representation of the sequence of stimuli during the Test phase.

Counterbalancing. For each infant one of the novel objects was used as the initial object and the other object was used as the post-change object. We counterbalanced across infants which object was used as the initial and which one was the post-changed one, and which of the two pseudowords (pota, szemo) was used as the label for the initial object in the induction phase. For each infant, the pseudo word which was not used as the label in the induction phase was used as the untrained word in the test trials. At test, trained and untrained words were presented in alternate trials, and whether trained or untrained word was presented first was

counterbalanced across infants. The sides in which the objects were presented was held constant for the first two trials and then switched and held constant for the next two trials, with which side the pre-change object was first presented, counterbalanced across infants.

4.2.1.5 Data Analysis

To be included in the final sample, infants had to fulfill the following predetermined criteria: (1) they had to look at the screen for at least half of the total duration of the baseline and the measurement periods; and (2) they had to contribute at least two valid test trials, one per condition. All included infants were attentive throughout the induction phase. Infants in both groups contributed a similar number of valid test trials (ostensive group: $M = 3.62$ trials, $SD = 0.50$; non-ostensive group: $M = 3.69$ trials, $SD = 0.60$).

To assess infants' referent selection at test, two areas of interest (AOI) were defined in the test display: (1) the region occupied by the initial object, and (2) the region occupied by the post-change object. We calculated the proportion of looking to the initial object (PLI) by dividing the duration of looking to the initial object by the total time spent looking at both the objects: $PLI = \text{looking at the initial object} / (\text{looking at the initial object} + \text{looking at the post-change object})$. The PLIs were computed separately for the baseline as well as the post-naming measurement period. The change of PLIs from the baseline to the post-naming period would indicate the effect the trained or untrained label had on the infants' reference selection. Namely, a higher PLI at post-naming than at baseline would be taken as evidence of referent selection.

4.3 Results

A three-way mixed ANOVA on PLIs with segment (baseline v. post-naming) and condition (trained vs. untrained) as within-subject factors, and group (ostensive group v. non-ostensive group) as a between-subject factor revealed no significant main effects, but a significant two-way interaction between segment and condition, $F(1,30) = 5.885$, $p = 0.021$, $\eta_p^2 = .164$, and a significant three way interaction between segment, condition and group $F(1,30) = 5.132$, $p = .031$, $\eta_p^2 = .146$ (Figure 4.3).

To resolve the three-way interaction, we conducted separate ANOVAs with segment and condition as a within-subject factors for each group. For the ostensive group, this analysis yielded no significant main effects but a significant interaction between segment and condition, $F(1,15) = 7.918$, $p = .013$, $\eta_p^2 = .345$. Infants in the ostensive group but not those in the non-

ostensive group were expected to selectively orient to the initial object in response to the trained label during post-naming. To test this prediction, follow-up paired t tests were run.

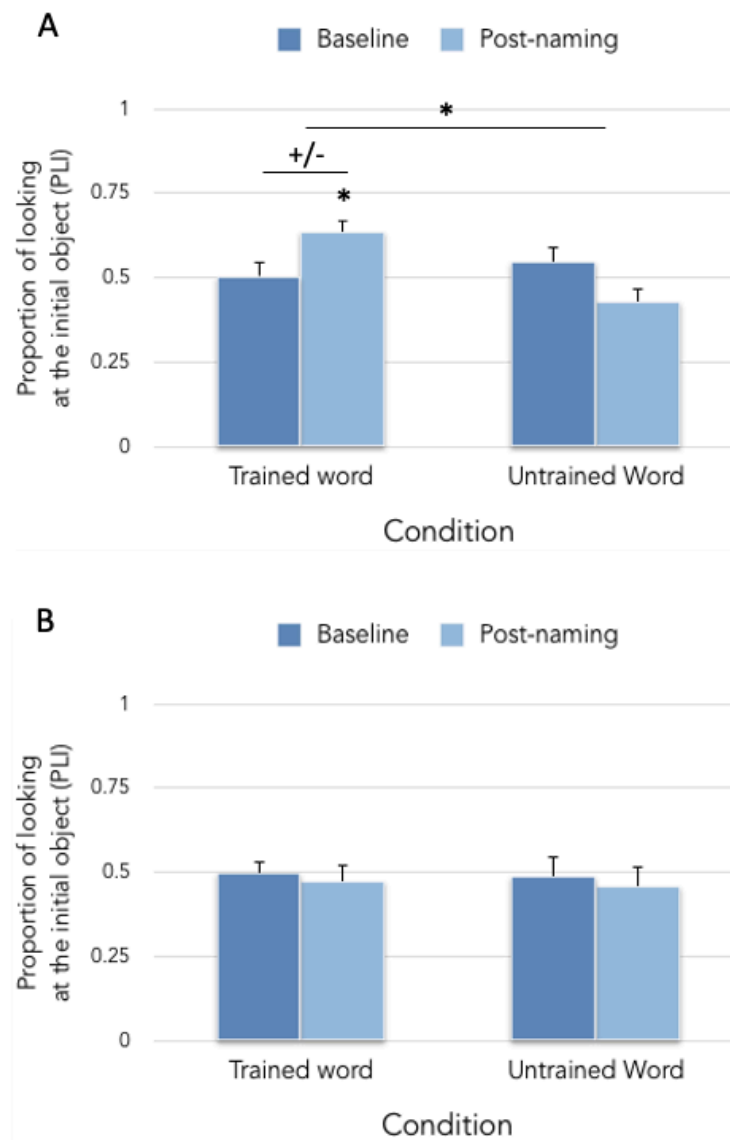


Figure 4.3. Proportion of looking at the initial object split by phase and condition in (A) the ostensive group and (B) non-ostensive group. Error bars depict standard error of the means. Significant effects are indicated with asterisks: * $p < .05$, +/- $p = .11$.

This interaction was due to the fact that, in line with our prediction, infants in the ostensive group tended to increase their looking at the initial object from baseline to post-naming, $t(15) = 1.716$, $p = .107$, $d = .43$, 95% CI = [-0.03, .29], unlike infants in the non-ostensive group whose looking at the initial object was comparable between baseline and post-naming, $t(15) = .552$, $p = .589$, $d = .14$, 95% CI = [-0.13, .23]. Furthermore, at baseline infants in the ostensive group looked to the initial object equally long in both conditions, $t(15) = 0.978$, $p = .344$, $d = -0.245$, 95% CI = [-0.13, 0.05], (trained word: $M = 0.505$, $SD = 0.176$;

untrained word: $M = 0.545$, $SD = 0.132$), while at post-naming they looked longer to the initial object in the trained than in the untrained condition, $t(15) = 2.826$, $p = .013$, $d = 0.706$, 95% CI = [0.051, 0.363] (trained word: $M = 0.635$, $SD = 0.192$; untrained word: $M = 0.428$, $SD = 0.168$). Finally, at post-naming, infants looked at the initial object significantly more than expected by chance (.5), $t(15) = 2.807$, $p = .013$, $d = 0.70$, 95% CI = [.03, .24], only in the trained-word condition (untrained word: ($t(15) = 1.709$, $p = .108$, $d = 0.43$, 95% CI = [-0.16, 0.02])). During baseline infants were at chance (trained word: ($t(15) = 0.118$, $p = .908$; untrained word: ($t(15) = 1.354$, $p = .196$), showing no preferential looking to either the initial or the post-change object. Similar analysis for the non-ostensive group showed no differences from across conditions or differences from chance (all p s > .5).

4.4 Discussion

Infants in this experiment displayed a different word recognition pattern depending on which induction they received, ostensive or non-ostensive. Only infants who were introduced to the initial object in a communicative ostensive manner prior to labeling tended to increase their looking to this object from baseline to post-naming in a word-mapping test. Importantly, they did so selectively upon hearing the trained word, but not upon hearing a novel untrained word. This suggests that infants mapped the trained word onto the initial object and were able to reidentify it upon labeling at test. Conversely, infants who were introduced to the initial object in a non-ostensive way showed no increase in looking during word-mapping test. They looked equally long to both objects whether presented with trained or untrained words throughout baseline and post-naming. This indicates that they failed to link the trained word with either of the objects.

We have proposed that ostensive reference leads to kind-based encoding of the referenced object, hence allowing for its identification as a familiar kind member (Chapter 2) or inducing the creation of a placeholder for a new kind. This would then explain how predicates postulated on the single exemplar can be linked to an object kind, and, relatedly how object labels can be fast mapped onto object kinds and not to the objects themselves, a question that many have tried to explain (Markman, 1990; Waxman, 1999; Rhematulla & Hall, 2009; Gelman & Taylor, 1984). The results reported in this chapter show that 18-month-old infants might be aided by ostensive reference to home in on the object kind as the target of the reference and tie the label to it. They add onto previous studies that have shown that ostensive referential signals trigger kind-based representation of novel objects and link subsequently explicated non-obvious property to kinds (Futo et al., 2010; Butler & Tomasello, 2016). Our results are also in line with studies that had previously dissociated label

presentations from their ostensive referential packaging, resulting in infants failing to utilize the label's potential to create a kind out of the commonly labeled tokens by categorizing them together (Fulkerson, Shall, & Haas, 2002; Keates & Graham, 2008).

Our proposal and results are also supported by studies that show that infants are more likely to map labels onto kinds when they have an existing placeholder for the kind opened. Two studies indicated that infants are more likely to learn labels for potential conceptual categories that they have accessed prior to labeling events. Pomiechowska and Gliga (2019) showed that 12-month-olds are more likely to learn category labels for object categories that they have already opened than when the labeling is applied to objects for which they have not had a prior chance of opening a category placeholder for. Yin and Csibra (2015) showed that 14-month-olds, after being given evidence that an agent played the role of a 'chaser' (a concept that infants at this age already possess), vs. agents that had no conceptually relevant function or role but shared common visual features, the infants only learned the ostensively delivered labels for the conceptually defined agent, but not for the agent defined only by their perceptual appearance.

However, our study has limitations in conclusively claiming that infants did indeed attach the label to the kind representation. Namely, we did not test whether they would extend the learned label to further exemplars of the kind and it is not even clear how they would identify further exemplars. But given prior research indicating that children take ostensively conveyed labels as kind labels, we think the 18-month-olds in our study were also mapping the label to a kind, while in the non-ostensive context they were unsuccessful at learning the word.

Why did not the infants map the new word onto the post-change object? This might appear puzzling since, though they did not receive ostensive reference to the object prior to labeling, the labeling itself is an ostensive act and infants can learn labels for hidden objects when the person who labels them clearly indicates their location (Baldwin, 1993). Note, however, that labeling in our study was performed using adult-direct speech known to be less effective at promoting learning than infant-directed speech (e.g., Hernik & Csibra, 2015). Furthermore, infants were not directly addressed by the communicator. The interpretation of the studies claiming that 18-month-olds can learn from indirect labeling instances (Floor & Akhtar, 2006; Akhtar, Jipson, & Callanan, 2001) is not straightforward: a closer look at their methodology reveals that the children were introduced to the object and its label while the experimenter engaged with an adult in child-directed ostensive referential communication about the object. It is possible that given the child-directed nature of the interaction, the children assumed that the ostensive referential interactions were actually directed at them, and

hence were able to learn the labels, unlike in our non-ostensive condition. Indeed, Butler and Markman (2016) found that even 3-year-olds continue to expect a person, who was ostensibly communicative to them within the immediate context, to continue to do so when, from an adult perspective, she had stopped communicating with them).

If labels were associated to closely co-occurring referent objects, as claimed by some associationist theories, the infants in our study should have linked the label to the object presented to them immediately after labeling. However, we did not find this even in the non-ostensive condition, where the infants failed to map the label onto either of the two objects. The failure to map the label to the initial object in the non-ostensive condition was unlikely due to the lack of attention to the initial object: the object was highlighted by the adult's actions and engagement with the object, and infants followed her object manipulation closely. Our design ensured that the difference between the ostensive and non-ostensive conditions was subtle, and only the ostensive and referential signals were missing from the non-ostensive condition prior to the labeling phase.

Our proposal may seem similar to what has been called the social pragmatic theory of word learning, which argues that infants can learn to map words onto their referent by inferentially interpreting the communicator's intended referent (Tomasello, 1999; Bohn & Frank, 2019). However, our position is different. We do not claim that infants infer that the intention of their communicative partner is to refer to a whole kind rather than to the pinpointed object itself. Instead, our proposal is that infants' default interpretation when objects are ostensibly referred is that they are being communicated to about a kind – unless the context further defines that the reference is meant to be applied to a specific individual (Hall & Rhemtulla, 2014).

Chapter 5

Conclusions

*The trouble with having an open mind, of course, is that people will insist
on coming along and trying to put things in it.*

Terry Pratchett, Diggers

The studies reported in this thesis are aimed at empirically validating the theoretical proposal of nonverbal generics (Csibra & Shamsudheen, 2015). The proposal grew out of the hypothesis of natural pedagogy (Csibra & Gergely, 2006, 2009), which was developed to explain how infants and children acquire opaque cultural knowledge from others nonverbal communicative acts explicitly directed at them. The main tenet of that hypothesis was that infants are sensitive to signals that indicate that they are being addressed by communication (ostensive signals), expect deictic referential signals in ostensive contexts, and display ‘genericity bias’ to interpret nonverbal communication as expressing generic cultural knowledge. This work built on the foundation of previous research reporting evidence for these claims: infants show a precocious ability to recognize communicative intentions made evident by ostensive signals and they expect to be communicated about something out there in the world (Csibra & Volein, 2008; Senju & Csibra, 2008; Hernik & Broesch, 2019), and show a predisposition to encode information thus conveyed as having relevance beyond the immediate context of the communication (Butler & Tomasello, 2016; Okumura et al., 2016; Egyed, Király, & Gergely, 2013; Futó et al., 2010; Király, Csibra, & Gergely, 2013; Träuble & Bätz, 2014; Yoon, Johnson, & Csibra, 2008; Okumura et al., 2020). Research with older children indicated that children may be interpreting information conveyed ostensive as having stronger inductive potential or more generalizable (Butler & Markman, 2012, 2014).

The proposal for nonverbal generics offers one particular way of implementing the ideas of natural pedagogy without relying on genericity bias and inductive generalization. The main point of the proposal is that objects in human communication can play the role of representing *any* object of the same kind, i.e., they can be ad-hoc symbols for their own kind. As we explicated it in Chapter 1, if infants take deictically referred objects as playing this role in communication, they would automatically extend predicates, whether they are labels or functional properties, as extending to the whole kind. Such interpretation of a communicative act would thus provide infants with a nonverbal version of a generic sentence.

This dissertation attempted to test three non-trivial predictions derived from this proposal: (1) that ostensive reference to an object induces kind based representation of it (Chapter 2), (2) that predicates attached to ostensively presented objects are generalized to other objects of the same kind and, just like generic knowledge, are resistant to counterevidence (Chapter 3), and (3) that verbal labels are attached to kind placeholders, rather

than to objects, which in turn are automatically generated for ostensibly referenced novel objects. The three studies adopted three different methodologies to gather converging evidence on the questions addressed. The experiments in Chapter 1 relied on the most widespread method of infancy research: looking time measurement; the study reported in Chapter 3 measured behavioral responses; and the experiment in Chapter 4 used eye tracking technology.

5.1 Summary of Findings

5.1.1 Nonverbal Reference Facilitates Object Individuation (Chapter 2)

The experiments in Chapter 2 capitalized on the well-established finding in infant research, according to which young infants would only individuate multiple objects in the absence of spatiotemporal evidence if they encode them in terms of their kinds. This was shown by earlier studies in which the objects on the scene were either labeled (Xu, 2002) or their function was demonstrated (Futo et al., 2010). Both these attributes were attached to objects by ostensive communication, and both provided quasi-conceptual definition of the kinds that the referred objects belonged. We hypothesized that the first of these components was necessary for kind-based representation but the second one was not - as long as the infants would recognize the objects as belonging to familiar kinds. Thus, we presented infants with familiar objects in an ostensive-referential context and tested whether they individuated them.

We found that they did so only if the two objects belonged to two distinct kinds. This showed that the exclusivity logic (an object cannot belong to two kinds at the same time) of object individuation comes from conceptual kind knowledge, but, in order to engage such knowledge, the objects have to be represented as exemplars of their kinds. Our results indicated that ostensive reference to them induces this kind of representation of referents even at the age when infants would not spontaneously produce them. We also attempted to test a further prediction drawn from our proposal: that the kind knowledge that supports kind-based object individuation of distinct objects can come from different sources. This prediction was not supported by our results, but we think that the particular operationalization of these studies made the task too difficult for 9-month-old infants.

5.1.2 Acquiring Generic Knowledge without Induction (Chapter 3)

The study described in Chapter 3 tested the most important prediction of the proposal, that ostensive action demonstration of a property on novel object is interpreted as a generic property of the kind. That infants tend to generalize their newly acquired knowledge had been tested in many earlier studies (Graham, Zepeda, & Vukatana, 2020 for a review), and it has also been demonstrated that 2-year-old and older children are more prone to generalize object properties if they had acquired them in communicative contexts (Butler & Markman, 2012; 2014; Butler & Tomasello, 2016). Our study went further and asked whether these phenomena of rapid generalization were based on ordinary inductive processes or were more akin to learning from generic statements. The crucial difference between these types of learning is how the acquired knowledge responds to counterevidence. Thus, we tested not only whether infants generalize an ostensively demonstrated property to a new exemplar of the same kind but also how they modulate their expectation after encountering counterevidence.

We found that 18-month-olds were resistant to such counterevidence – as long as they acquired their knowledge of the novel property by ostensive demonstration. Merely observing an object property also made infants hypothesize that the property extends to further kind members, but if this expectation was not confirmed, they rationally re-evaluated their expectation, suggesting that they were engaged in inductive learning. In contrast, learning from nonverbal communication, just like learning from generic sentences, tended to generate knowledge that was difficult to eliminate by counterevidence.

Further manipulations of this study showed that, at this age (and also at 2 years of age, see Butler & Tomasello, 2016) visual similarity is not, but having a common label is sufficient to treat objects as belonging to the same kind. This result shows the special power of words: while ostensive communication may induce kind-based representation, it cannot specify whether two or more objects belong to the same kind. This study demonstrated that verbal labels fulfill this role quite well.

5.1.3 The Role of Ostensive Reference in Mapping Labels to Objects

Chapter 4 approached the main proposal in a different way, asking whether ostensive reference is uniquely capable of inducing infants to set up a kind placeholder for a novel object.

The study assumed that when 18-month-old infants learn a novel label for a novel object, they do not attach the label to the object itself, but create a new kind, of which the object is a representative exemplar, and link the label to this kind placeholder. Thus, if infants have already generated such a placeholder for an object, they will attach the label to that – if they haven't, they set this up at the time of labeling. Crucially, if the object is not present when the kind placeholder is produced, it may not be included as an exemplar of the representation. The elaborate manipulations we used in this study served the purpose of generating such a situation.

Our findings indicated that, in the absence of previous ostensive reference to an object, a novel label applied to an invisible object was not attached either to a previously seen or to a later appearing object. In contrast, if an object that later became the possible referent of labeling had been previously the subject of ostensive reference from a communicator, infants readily learned that the object is a potential referent of the label. This result is compatible with the proposal that ostensive reference induces kind based, and even *novel* kind based, representation of objects. In addition, this result suggested a possible route of learning novel words for objects in ostensive contexts.

5.2 Conclusions

The three studies presented in this dissertation confirmed important non-trivial predictions from the proposal of nonverbal generics. They all suggest that infants tend to represent ostensively referred objects as representatives, or even symbols, of their kind. Such a tendency would make them capable of learning generic knowledge from others even in the absence of the linguistic skills that are necessary to interpret generic sentences. Such a conclusion does not entail that infants would only learn generic knowledge by infant-directed communication or that this route would represent the primary way of how infants acquire cultural knowledge. Nevertheless, learning by nonverbal generics provides infants a valuable shortcut to knowledge – a shortcut that requires no inductive inferences or hypothesis testing, and a learning mechanism that is probably not available to the infants of non-human species.

We cannot conclude either that our findings have conclusively proved the existence of this species-specific learning mechanisms. All our results are open to alternative explanations that do not involve novel notions, such as learning from nonverbal generics, and we discussed some of these alternatives in the preceding chapters. Nevertheless, we recruited three different methods to probe different non-trivial predictions drawn from our hypothesis. Any alternative theory that intends to challenge our hypothesis should account for the converging evidence

gathered from each study. We are aware of the fact that, even if our findings support the proposal of nonverbal generics, they leave open many questions, both empirical and theoretical. We close the dissertation by raising some of these questions.

5.3 Further Questions

5.3.3 Reference to Particular Objects

The proposal that ostensive deictic reference is interpreted by infants as specifying a symbol of an abstract kind, rather than the particular object that is physically present seems paradoxical. How would they ever learn that when someone is pointing to an object, she is expressing something about that object, rather than the kind it represents? For example, how do they understand a request for an object?

We suggest that infants can achieve this feat by learning the social contexts and predicates that require the restriction of reference assignment to the object in hand. They may learn, for example, that requests are usually directed to specific objects, rather than to kinds. This idea implies that initially infants take any predicate as projectible and generalizable, even those that are very rarely act in that role, such as location. Topál et al. (2009) tried to explain the well-known A-not-B error in a similar way: ostensibly presented hiding may be interpreted by young infants as demonstration of location as a to-be-generalized property, which would then even survive the counterevidence of seeing the object hidden at a different location. It is not until about 12 months of age that children understand what a hiding-finding game is about, and from that point they are less likely to commit the A-not-B error.

The case that we make here for non-verbal generics is comparable to what Leslie (2007, 2008) and Gelman (2004) has argued for the interpretation of ambiguous assertions: namely, that generic interpretations are cognitive defaults. Just as we propose that, for infants, ostensibly delivered messages are interpreted as generic and it is the non-generic interpretations that need to be marked for them, linguistic generic expressions too have no explicit linguistic markers in any known natural languages (Dahl, 1985). Instead, it is the non-generic statements that are syntactically marked. Furthermore, verbal generic comprehension is evident early in the development despite having no markers that can readily signal that a generic interpretation is warranted (Gelman & Raman, 2003). It is conceivable that infants proclivity to acquire generic information via nonverbal generics sets the foundation for their seemingly precocious ability to comprehend verbal generic statements.

While this proposal seems counterintuitive, some findings seem to support it. For example, Meyer and Baldwin (2013) found that, unlike adults, 3-year-old children did not restrict predicates to the actual referents of statements when they were specified by pointing. Rather, they tended to interpret such statements as if they had heard a generic sentence. In fact, adults also interpret and remember ambiguous statements as generics (Leslie & Gelman, 2012). It is also noteworthy that while by 2 years of age children comprehend generic statements (Gelman & Raman, 2003; Graham, Nayer, & Gelman, 2011), it takes them much longer to understand various quantifiers that restrict reference to particulars or sets of them.

Nevertheless, most studies on early receptive communication assume that infants interpret deictic gestures (gazing, pointing, showing objects) as directed to particular objects. For this reason, the empirical evidence on this issue is scarce.

5.3.3 Labels

The other paradoxical feature of the studies presented in this dissertation is that, while all of them adopted object-labeling episodes some way, the hypothesis that generated these studies is called ‘nonverbal generics.’ It may be relatively uncontroversial that the initial learning of labels can be supported by nonverbal generics (Chapter 4). We also argued that in a certain role, namely in the role of being able to induce kind-based representations, ostensive nonverbal reference can replace labels, at least for familiar objects (Chapter 2). But they cannot be replaced in other roles, such as that they can be unambiguous arbiters of which objects belong together under the same kind concepts (Chapter 3). The recognition of this role of labels may be interpreted as the main function of this linguistic device, as this is the one that provides more services to learners than what nonverbal generics can offer.

The interesting question that comes from this point is how far this role of labels can go. It is well known that object labels facilitate categorization (see Ferguson & Waxman, 2016 for a review). But if labels can define what objects belong to newly created placeholders without specifying any deeper information about the underlying concept, such a role opens the possibility to purely extensionally defined categories and consequently to linguistic determinism.

5.3.3 Pretense

In Chapter 2 we demonstrated that ostensive reference to a familiar object induces the object to be represented in terms of its own kind. Pretense is a context in which ostensive reference is amply used, and hence we can expect kind-based representations of objects to be

triggered. But substitution pretense involves the understanding that an object that is ostensibly referred to stands not for its own kind but for another kind. Intuitively this would seem to be a complex ability to master, and yet substitution pretense is an early emerging skill (Hopkins et al., 2016). Children achieve such sophistication of pretend play towards the end of their second year, and perhaps treating objects as symbols in communication from the beginning prepares them for this achievement. If an object can stand for any object of its own kind for infants, they are only a small step from understanding that it can also act as a symbol of another kind of object. In other words, with this small step they would be able to be engaged in substitution pretense. Thus, if the hypothesis defended in this dissertation is correct, what infants have to learn in order to understand pretense actions is not that objects can act as symbols, but that they can occasionally represent other kinds of objects.

5.3 Summary

Thinking in terms of kinds is an important ability that allows one to go beyond being limited to the idiosyncratic structure of the world and to communicate and learn about generic, culturally shared information. This thesis contributes to the understanding of how young preverbal infants, who do not spontaneously encode objects in terms of kinds, acquire generic knowledge by being predisposed to interpret ostensive referential communication as prompts to think in terms of kinds.

Being susceptible to take a referent as a representative of its kind allows them to gain generic knowledge from nonverbal ostensive communication, just as older children and adults do from verbal generic statements, bypassing the slower process of acquiring generic knowledge by inductive generalization. The research reported here gives evidence for young infants' capability to tap into ostensive referential communication as potential expression of non-verbally expressed generic information. We show that this might be an early emerging ability present at least from around 9 months of age, the earliest age we investigated in the studies reported here. Furthermore, we demonstrated not only that infants learn generic information in a one-shot mechanism from nonverbal ostensive referential communication, but that information so acquired displays also the signature of information acquired via verbal generic statements: resistance to counterevidence. This work makes important contribution to our understanding of how the development of human infants is subserved by specialized socio-cognitive mechanisms that are uniquely evolved to utilize the human-specific communicative practices.

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