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Coming from a world without objects

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While research on object individuation assumes that even very young children are able to perceive objects as particulars, we argue that the results of relevant studies can be explained in terms of feature discrimination. We propose that children start out navigating the world with a feature-based ontology and only later become able to individuate objects spatiotemporally. Furthermore, object individuation is a cognitively demanding achievement resting on a uniquely human form of enculturation, namely the acquisition of deictic demonstratives. We conclude by outlining empirical expectations for operationalizations of our proposal.

KEYWORDS

demonstratives, infant cognition, kind-bias, object individuation, reference

1 | INTRODUCTION

The advent of language acquisition and cultural learning lies in infants' capacity to share attention to an object with an adult interlocutor: Joint attention. Within the referential triangle of infant, caregiver, and object, children can learn *about* the environment by following their interaction partner's actions and emotions as well as by connecting the language they hear to salient and relevant aspects of a situation.

Developmental research has made remarkable contributions to our understanding of the socio-cognitive processes involved in the coordination of minds necessary for triangulation. The "social side" of triangulation (child–adult)—its functional principles and effects for the development of shared intentionality—has been extensively investigated (Baldwin & Moses, 2001; Gliga & Csibra, 2009; Tomasello, 2010; Tomasello & Carpenter, 2007; Tomasello, Carpenter &

Liszkowski, 2007). The "referential side" (child-object) of triangulation, however—its mechanics and impact on skills of referring to objects—has received much less attention (but see Mattos & Hinzen, 2015). Instead, the "referential side" of triangulation is considered a precondition of shared intentionality. An implicit assumption in this area of research seems to be that in situations of shared attention, the child individuates the object in the same way as her adult interaction partner. This assumption is based on evidence produced by extensive research on infants' behaviors when confronted with a variety of scenarios involving visible objects (cf., e.g., Younger & Cohen, 1983, 1986; Spelke, Kestenbaum, Simons & Wein, 1995; Xu & Carey, 1996; van de Walle, Carey & Prevor, 2000; Cohen & Cashon, 2001; Needham, 2001; Johnson, 2009; Moore & Meltzoff, 2009).

Since object individuation in infants is taken for granted in most interpretations, it is understandable that few studies have explored individuation in situations of joint attention. Xu and Carey (1996) and Xu, Cote and Baker (2005) found that 9-month-old infants succeeded in identifying objects by features earlier when experimenters verbally referred to objects. But above all, pre-linguistic children, when presented with verbal information about objects in triangulation situations, do not understand this information as *episodic*, that is, as specific to the individual object referred to by the interlocutor (Csibra & Gergely, 2009; Hernik, Sperber & Gergely, 2018; Yoon, Johnson & Csibra, 2008). Instead, children systematically "generalize" information they receive to any object with similar surface features. These authors conclude that young children interpret information about objects in a generic way. Building on such empirical evidence, Csibra and Gergely (2009) argued that this *kind-bias* is part of a uniquely human capacity for cultural transmission that has been termed "natural pedagogy." As a central hypothesis of natural pedagogy, the authors propose that "children expect to learn something generalizable in ostensive-referential contexts rather than just become informed about particular episodic facts that obtain only in the 'here-and-now'" (Csibra & Gergely, 2009, p. 151). Interestingly, Csibra and Gergely interpret this as a human-specific evolutionary social adaptation. However, an alternative possibility is that young children lack the ability to understand information about specific objects.

In this article, we critically discuss the assumption that infants individuate objects as cohesive entities that move continuously through space and time. Objects understood in this way have been described as Spelke objects (Carey, 2009), and the corresponding view is generally known as the *object-first interpretation*. Although the object notion involved is considered minimal, it still conceptualizes objects as self-same entities that persist through time and are distinct from one another. In Section 2, we present analytic considerations suggesting that individuation may be more cognitively demanding than commonly assumed. We present arguments to highlight that individuation of objects is a sophisticated capacity and that it presupposes an understanding of identity that researchers should be cautious about attributing to infants 1 year old or younger. In Section 3, we will summarize general criticisms of paradigmatic experiments supporting the object-first interpretation and present the information processing account due to Cohen, Chaput and Cashon (2002) as a viable alternative. According to the more parsimonious interpretation that we defend, infants lack an object ontology. Instead, they are sensitive only to perceptual features, their similarities, and patterns of features. In Section 4, we provide feature-based re-interpretations of paradigmatic experiments that are regularly taken to demonstrate that infants conceive the world as consisting of objects. In Section 5, we introduce a suggestion for possible experimental protocols that could test this notion, since they would not allow feature-based discrimination. These may offer a new perspective on young children's ability to individuate objects.

2 | THE COMPLEXITY OF REFERENCE

It is natural to assume that infants are able to individuate objects. After all, they continuously interact successfully with objects. It seems indeed counterintuitive that young children should lack the ability to individuate objects while displaying the ability to classify entities according to feature similarities. Grouping objects into appropriate categories appears to be more demanding than just individuating single objects. Moreover, object individuation is often seen as a kind of object classification by features. Individuating an object would mean recognizing the kind of which it is the sole exemplar. Object categorization is the focus of the vast majority of research on concepts in cognitive psychology. This may overstate the role of building category concepts and neglect the conceptual importance of reference to particulars and individuals (Blok, Newman & Rips, 2005).

The object-categorization view is a corollary of a classical account of linguistic meaning according to which meaning consists of name-object assignments (Outler, 2006; Mill, 2012). This variation of a referential theory of linguistic meaning holds that adults refer to objects and name them in a spatiotemporally defined world. Children, then, acquire a language by learning correspondences between names and objects (Lycan, 2008). Language acquisition would then merely consist of memorizing these name-object assignments. The ability to refer to individual objects is just taken for granted.

The referential theory, however, has been sharply criticized. Wittgenstein (1969) points out that many of the words we use do not refer to spatiotemporal objects or events and, therefore, that the referential theory is incomplete. Chomsky argued that even proper names, for which the word–object model would be most plausible, do not work like word–object assignments (Chomsky, 2000; Sheehan & Hinzen, 2011). Moreover, according to internalist semantics, names do not directly refer to the objects with which they seem to be associated (Pietroski, 2018; Speaks, 2019). Indeed, questions as to how object reference can be conceptualized have caused frequent debate in 20th-century analytic philosophy (cf., e.g., Campbell, 2002; Donnellan, 1966; Evans, 1982; Frege, 1892; Kripke, 1980; Quine, 1960; Russell, 1905; Searle, 1958; Strawson, 1959; Tugendhat, 1976). The human capacity to refer to objects is not yet fully understood.

The meaning of proper names took center stage in historical theorizing about reference. From the discussion of names, however, the insight was generated that understanding the functioning of other referring terms can be central for understanding reference. Most importantly, reference is facilitated by the functioning of terms whose reference shifts with the perspective of the speaker and that are part of an interdefined substitution system—indexicals (pronouns such as "you" or "me") and demonstratives (such as "here" or "there"; Evans, 1982; Tugendhat, 1976). Sentences involving indexical expressions are not reducible to sentences without indexicals (Castañeda, 1966, 1968; Kaplan, 1979; Perry, 2000) and non-indexical reference depends on indexicality (Evans, 1982; Tugendhat, 1976). With this in mind, reference to objects can be seen as a basic grammatical category rather than a lexical category (Hinzen & Sheehan, 2015). Indexicals have no lexical content, but the "grammar of their use" fully determines their meaning. Thus, pronouns can express reference without lexical content—something that no nominal ever does (Martin & Hinzen, 2014; Hinzen & Sheehan, 2015, p. 173).

Unlike other spatial expressions, demonstratives form a class of expressions that are universal, possibly "primordial in phylogeny" (Diessel, 2006; Peeters & Özyürek, 2016), and constitute a major source of functional morpheme development (Diessel, 2014). The demonstrative pronoun ("that" in English) is one of the earliest and most frequent linguistic utterances made by young children (Clark & Sengul, 1978). Other elementary demonstratives and local adverbs ("this", "here", and "there") are used less often but are still among the 15 most commonly used

words in English (Ibid.). Most languages provide terms to deictically mark different distances from the speaker and to refer to the same individual from different perspectives (Anderson & Keenan, 1985). Demonstratives do not derive from other word roots and are, therefore, considered elementary (Diessel, 2006).

Overall, the capacity of reference appears to be more complicated than initially assumed. The role of indexicals in the *acquisition of reference to objects* may have been underestimated. The following adapts the central line of argument from Evans (1982) and Tugendhat (1976).

1 Referring to features is cognitively less demanding than referring to objects. To refer to features, one needs the ability to perceptually discriminate and compare features, to register feature similarities, distinctions, and changes, and to react systematically to different features. Reference to objects presupposes reference to features but not vice versa.
2 Commonly, objects are minimally regarded as units that move as connected wholes. They are solid, cohesive bodies moving continuously in space and time (cf. Cacchione & Rakoczy, 2017, p. 580). This minimal notion of an object presupposes that objects are considered as the same or distinct. Individuation of and reference to objects requires a concept of identity, which in turn presupposes a frame of reference that provides identity criteria. Note that having a concept of identity requires only an implicit understanding of that concept. For an implicit understanding, infants must be able to behave according to the concept-defining rules. They need not represent the rules themselves.
3 Insofar as spatiotemporal coordinates provide the identity criteria for objects, the acquisition of a spatiotemporal coordinate system involves the acquisition of a concept of identity. Such an abstract coordinate system is different from feature-based spatial orientation capacities and provides the means to conceptualize entities independently of their intrinsic perceptual features. An object may be tracked as one and the same—regardless of changes in its appearance. Note that no more than one object could ever have this feature at a particular point in time. Therefore, objects may be uniquely identified by their location in space and time.
4 Different ways of acquiring singular terms may be conceivable. However, for conceptual reasons, a unique opportunity for the establishment of such a coordinate system can be seen in the acquisition of a binary substitution system of strictly inter-defined terms, which completely differs in its usage rules from the term-system used for features (i.e., general terms/predicates). The usage of the local adverbs "here" and "there" is not bound to features but depends on the relative position of speakers in communicative situations—as does the usage of the demonstratives "this" and "that". In order to use these deictic terms correctly, one has to refer to the same feature by two binary, interdefined, and different terms from different positions in space. A child knows the meaning of "this" only if she realizes that what she calls "this", from her position, has to be called "that" from another position. And she knows the meaning of "here" only if she realizes that what she calls "here" has to be called "there" from a different position.
5 Acquiring such a substitution system is demanding and occurs much later in childhood than other vocabulary terms. Young children use such deictic terms in their earliest utterances. This suggests awareness of the flexibility of reference to the focus of joint attention early on—even though they may be unable to use those terms as substitutes for each other until they are older. Later, they are able, reliably, to prioritize relative location of the referent rather than any other feature in conversing with their interlocutor, and to take the interlocutor's own perspective into account (Peeters & Özyürek, 2016). The stepwise development of such a substitution system should lead to the omission of attention to features and would establish a primary level of identifiability in space and time.

6 Assuming that mastery of demonstratives is related to establishing a spatiotemporal coordinate system, realizing that two different terms must, under certain conditions, stand for each other should lead to the conceptual construction of one referent for both terms. As the usage rules do not depend on features but spatiotemporal position, their common referent cannot be a feature but has to be something else: A place or an object. Thereby, demonstratives become the first singular terms that children become sensitive to which is a crucial step in the development of propositional thought altogether. These substitutions form the basis of a feature independent term-system as a whole.
7 The correct use of demonstrative terms depends on spatiotemporal relations between speakers and what they talk about as well as on how the terms must be substituted for each other. Based on this, children develop a spatiotemporal coordinate system and establish a term-system to interpret featural data in a feature-independent way, namely, in terms of spatiotemporal position.
8 Thus, features and combinations of features which can be discriminated by their places in time and space can be reidentified and appear as objects.

Against this background, it appears that reference to objects and, thus, the individuation of objects itself is a highly complex matter closely related to the reference to and individuation of places in space and time (Mattos & Hinzen, 2015).

Reference to object-intrinsic features (shape, color, texture, etc.) is cognitively simpler. Following the principle that the attributed cognitive capacities should not be more complex than required for an explanation of the observed phenomena, we should refrain from assuming from the outset that young children refer to objects. The tendency to interpret information generically is just what one would expect from a cognitive agent that is unable to refer to objects. Nevertheless, Csibra and Gergely (2009) take infants' ability to individuate objects as a factum and interpret the "kind-bias" of young children, as well as adults, as an additional cognitive achievement rather than a lack of ability to individuate objects (cf. Csibra & Shamsudheen, 2015).

Theoretical considerations lead us to the insight that individuating objects can be cognitively more demanding than feature-based processing, and that kind-bias may result from infants' inability to individuate objects. Nonetheless, the view that infants can individuate objects is widely accepted based on empirical studies. In the following section, we review several paradigmatic studies which have led to the inference that infants can properly individuate objects.

3 | A CRITICAL DISCUSSION OF THE OBJECT-FIRST ACCOUNT

How infants conceive of objects in the world has been a focus of scientific attention since Piaget's (1953, 1954) seminal research on object permanence in the "sensorimotor" stage of infancy and early childhood. Research on object segregation (Needham, 2001; Needham & Baillargeon, 1998), object individuation (Spelke et al., 1995; Xu & Carey, 1996), object identification (Tremoulet, Leslie & Hall, 2000), as well as object permanence (Baillargeon, 1986; Moore & Meltzoff, 1999; Piaget, 1953, 1954) has contributed to our understanding of how infants learn to individuate objects. Furthermore, causal learning (Sobel, 2009) and early arithmetic (Cohen & Marks, 2002; Wynn, 1992) draw heavily on infants' ability to individuate objects.

The standard interpretation of findings on object individuation is known as the *object-first* hypothesis (Xu & Carey, 1996). According to this hypothesis, children organize information in their visual field in terms of space, object, and movement, much like adults do (Xu, 2007; Xu, Carey & Quint, 2004). Spatiotemporal information about location and motion is thereby seen not only as the chief information adults use to identify objects (Kahneman, Treisman & Gibbs, 1992; Pylyshyn, 2001) but also as the basis on which infants learn to individuate objects (Spelke et al., 1995; Wilcox & Baillargeon, 1998; Xu & Carey, 1996). In accordance with the object-first hypothesis, the natural pedagogy account claims that young children are able to individuate objects irrespective of communicative actions (Hernik et al., 2018; Yoon et al., 2008). Only when they receive ostensively communicated information from a caregiver, do children attempt to interpret object aspects generically.

3.1 | Paradigmatic experiments supporting the object-first interpretation

We now present three of the most paradigmatic, widely cited studies on the issue. These are Xu and Carey (1996), van de Walle et al. (2000), and Yoon et al. (2008). Subsequently, we discuss general criticisms against the object-first interpretation before coming to an alternative framework.

Spelke et al. (1995) provided the classical looking-time violation-of-expectation paradigm forming the basis of the object-first hypothesis and influentially adapted by Xu and Carey. As in Spelke et al.'s first three experiments with 4-month-olds, Experiment 1 of Xu and Carey (1996) used paired, narrow occluders on a seen stage to explore how infants reacted to different object movement patterns across the stage. Following habituation, 10-month-old children watched objects appear from a central position. One object appeared from behind the left occluder, moved to the left side of the stage, and finally disappeared behind the left occluder. Then an identical-looking object came out from behind the right occluder, moved to the right side of the stage, and disappeared behind the right occluder. Finally, the occluders were removed, showing infants either one object behind each occluder ("two objects"—the expected event) or only one object behind one of the occluders ("one object"—the unexpected event). The infants looked longer when there was only one object behind one of the occluders. That is, the infants were not "misled" by the similarity of the objects into "believing" a single object had (somehow) materialized in two separate locations. These findings were replicated using similar looking-time procedures (e.g., Aguiar & Baillargeon, 1999; Wynn, 1992; Xu & Carey, 1996; among others).

van de Walle et al. (2000) established a violation-of-expectation manual-search procedure to investigate children's abilities to individuate objects. Children saw objects being placed and moved in and out of a box. First, two featurally different objects were simultaneously visible after being taken out of one box by the experimenter before they were put back into the box. In a second condition, one object was taken out and put back by the experimenter before the second object was taken out from the box and put back again. In both conditions, infants were allowed to search the box in the test phase and either found both objects (expected event) or only found one object (unexpected event). The dependent measure was the duration of search. Twelve-month-olds searched longer after the unexpected than the expected event in both conditions, whereas 10-month-olds did so only in the first condition in which both objects were visible at the same time.

Yoon et al. (2008) and Hernik et al. (2018) used a standard looking-time violation-of-expectation procedure to investigate the effects of verbal communication on object identification. Nine-month-old children saw an object which an adult either reached for (Condition 1) or pointed to while communicating ostensively (Condition 2). After a short occlusion, the object either changed its location or its features. In the reaching-for condition children looked longer when the object changed location than when it changed features. In the pointed-to/ostensive-communication condition, children looked longer when the object changed its features.

As children appeared surprised when presented with an unexpected number of objects (cf. Spelke et al., 1995; Xu & Carey, 1996; condition 1 in van de Walle et al., 2000), researchers concluded that they represent objects independently of their features. Furthermore, children tended to look longer at feature changes in the pointed-to/ostensive-communication condition but longer at location changes in the reaching-for condition. This led researchers to conclude that (a) infants interpret reaching behavior as being directed at a particular object, but (b) that ostensive communication cues the 9-month-old to look for features which could pertain to other objects.

3.2 | A general critique of the object-first interpretation

One line of argument against the object-first interpretation concerns the validity of looking-time measures for attributing higher-level cognitive capabilities. Except for van de Walle et al. (2000), investigations of object understanding in infancy are largely based on looking-time paradigms, mainly habituation–dishabituation experiments (for a discussion of the development of experimental paradigms see Krøjgaard, 2004). Looking-time patterns are interpreted as revealing infants' surprise, on which cognitive interpretations are based. However, looking-time patterns might instead give insight into perceptual preferences resulting from basic visual processing (Haith, 1998; Mandler, 1992). What is needed are complementary measures, including further physiological or behavioral variables (see for example, Kagan, 2008; Leung et al., 2016).

Our critique, however, is not methodological but theoretic. In addition to problems concerning the validity of looking-time experiments, there are more general concerns. From the observation that children behave in line with our expectations and ontology, it cannot, in principle, be concluded that they have the same ontology. The sensory environment can be perceived and interpreted in various meaningful ways, which could all result in similar expectations (Hirsch, 1997). Similar expectations about what will happen next, or about what will be the result of an event, can be constructed based on entirely different ontologies.

The fact that young children are surprised or not surprised by the same events that we would be surprised by only shows that, for example, they expect a specific kind of discontinuity, interrelation, or featural outcome within their own ontologies. From showing that children have expectations comparable to ours, we learn a lot about their behavior but little about their ontology. Hirsch (1997) points out that this underdetermination of ontologies is a fundamental difficulty of all experiments that measure similarities of expectations. Infant behavior that is similar to ours can be interpreted in terms of different ontologies without assuming that reference is made to objects in space and time.

Hirsch (1997) suggests that the observed subjects might, for example, be Quineans or Humeans or Strawsonians. Quineans would perceive certain discontinuous space–time portions of reality (Quine, 1960). Humeans would structure the world in momentary events and their

interrelations (Hume, 1978). Within a Strawsonian early childhood ontology, the perceived environment would consist of placed features and feature changes (Strawson, 1959). However, while similarities in expectations do not have to be the result of a shared ontology, differences in expectations can be considered as indications of different ontologies. In the case of infants, whose cognitive capacities are only just developing, the possibility of ontological differences is especially pertinent.

3.3 | An alternative: The information processing account

Interpretations that account for the experimental findings on object individuation in terms of perceptual processes can provide a more parsimonious interpretation. For instance, Cohen et al. (2002) offer an "information processing account" of perceptual development that can explain how stable representations of correlated features emerge. On Cohen et al.'s view, which assumes several information processing principles, features are discriminable properties of sensory impressions. Representations of high-level feature patterns are built up by hierarchically combining simpler feature representations (Ibid.). As a result of this hierarchical combination, features can be discerned at different levels of complexity.

Cohen and Younger (1984) note that what counts as a feature might change as a function of development. Expectations about future observations are formed based on these feature patterns and familiar regularities of feature changes. From this perspective, stable representations of correlated features count as object representations. Objects are thus seen as relatively high-level feature patterns. Errors in object individuation can then be explained by infants' tendency to fall back to simpler feature patterns when more complex patterns are not available (Cohen et al., 2002). Within this broader theoretical framework, for instance, an explanation of infants' performance in addition and subtraction events is presented in terms of familiarity effects and infants' preference for displays containing more stable correlated feature patterns (Cohen & Marks, 2002; however see also Carey, 2002; and Wynn, 2002 for a discussion of this perspective).

Nonetheless, the information processing account of Cohen and collaborators does not yet explain how the capability to individuate objects is acquired. Above, we have argued that object individuation requires a notion of identity. Information processing principles do not provide such a notion, nor does it emerge from their application. Tracking objects by features does not amount to the individuation of objects as self-same, persisting over time, and distinct from one another.

4 | REVISITING FINDINGS ON OBJECT INDIVIDUATION

What consequences do these considerations have for interpreting the results of Xu and Carey (1996), van de Walle et al. (2000), and Yoon et al. (2008)? Let us assume that infants are Strawsonian feature placers and that feature placers have a cognitive architecture similar to the information processing structure just presented. As feature placers, infants perceive hierarchically structured feature patterns and build perceptual expectations upon them. With this assumption in mind, we will now reconsider the above-presented experiments taken to support the existence of object individuation in infants. These experiments can be sorted into three groups.

(a) The first group of experiments—Xu and Carey (1996) and van de Walle et al. (2000)—will be used to show that a feature processing account can explain how infants' behavior can

conform to adult behavior without attributing an objects-ontology. One-object events may be distinguished from two-object events by comparing feature patterns across the whole array. Computational AI now illustrates how objects can be distinguished based on feature pattern analysis (e.g., Krizhevsky, Sutskever & Hinton, 2012). (b) The re-interpretation of the second group of experiments (second condition of van de Walle et al., 2000) demonstrates how we can explain behavior that deviates from adult behavior. To form expectations, children need not just be able to discern particular feature differences. They must also be familiar with the specific kinds of feature interaction. (c) The third re-interpretation (Yoon et al., 2008) serves to exemplify the role of different communicative acts. In particular, pointing and grasping constrain the feature segment on which expectations are based in different ways. This leads to the characteristic differences reported between the pointing-to and grasping-for conditions.

4.1 | Revisiting Xu and Carey (1996) and van de Walle et al. (2000) (first condition)

We would argue that in the experiments designed by Spelke et al. (1995) and in the respective first condition of Xu and Carey (1996) and van de Walle et al. (2000), children may perceive and react solely to feature changes in their visual field. Dissimilar visual features interact predictably and form a regular feature pattern. What we call "occlusion events" can be conceived as well-ordered changes of feature patterns by Strawsonian feature placers—corresponding to what is likely, given their learning history. Other events, such as those presented in the test conditions, are statistically unlikely and thus surprising—in their ontology as well as in ours.

"Objects" can be represented as feature patterns, and qualitatively similar patterns can be represented in several segments of the visual impression at the same time. Object recognition in AI illustrates this. Convoluted neural networks that extract low-level features from overlapping feature-sections of an image can extract which kinds of objects are visible in a scene. The nodes of a network, such as a convolution layer, are sensitive to certain feature parts of the image. These features are then further processed to obtain more complex features (or feature bundles) and, eventually, give the category of "objects" that are visible (cf., Krizhevsky et al., 2012). When the output layer is accordingly structured, such systems can be used to detect and categorize several "objects" at different "positions" in an image or video recording (e.g., Redmon & Farhadi, 2017). Notably, such detections are based on featural information alone. The process does not require objects to be identified from specific *a priori* feature lists (as in "classical" AI).

One-object events can correspondingly be distinguished from two-object events based on the differences between the array patterns. Computational agents can distinguish these based on the different patterns of visual impression they provide. Such information could well be used to form predictions concerning subsequent observations. Similarly, human intuitions about small number object arrays (numerosity judgments) can be formed without being able to count individual objects (Cohen & Marks, 2002).

There are computational models that explain both looking-time findings and manual-search results on object individuation (Mareschal, Plunkett & Harris, 1999; Munakata, McClelland, Johnson & Siegler, 1997). Other accounts focus on explaining the pattern of findings in A–B task experiments (Munakata, 1998; Thelen, Schöner, Scheier & Smith, 2001). None of these models require object representations. The observed behaviors can, in principle, be produced without the reliance on the concept of an object.

Event prediction can likewise be based on features alone. For example, Lotter, Kreiman and Cox (2016) built a recurrent convoluted neural network that predicted subsequent frames of a video clip. Such predictions worked without the representations of objects and broke down when the presented video sequences did not conform to the learned regularities, such as when the order of video frames was randomly scrambled.

With a focus on the early understanding of object permanence, Schlesinger (2003) presented a neural network that was trained on a simulation of some of Baillargeon's (1986) experiments. The network produced eye-movement outputs that were comparable to those obtained with infants. Lovett and Scassellati (2004) implemented a similar approach in a physical humanoid robotic system and presented it with a real-world version of the same experiment. The robotic system was trained on the habituation trials of one of Baillargeon's (1987) experiments. In these trials, a yellow cart ran along a sloped track briefly disappearing behind an occluder mid-sequence. After a few repetitions, the system habituated to the scene, meaning that it formed predictions about the observed feature changes, and moved the camera field away from the scene. It only used featural information, including a representation of the horizontal disparity between the left and right camera images. The pattern of camera movements was again comparable to the results from Baillargeon's infant studies.

In summary, two-object and one-object events provide different impressions in the visual array and, hence, can be distinguished by feature-placers that react to the visual impressions without having an object-ontology. Furthermore, predictions about courses of events can be made based on features alone, and the adult-like behavior of infants can, in principle, be explained without supposing object individuation. Schöner and Thelen (2006) provide a similar argument against early object permanence, from dynamic field theory.

4.2 | Revisiting Xu and Carey (1996) and van de Walle et al. (2000) (second condition)

The above point also provides the basis for explaining behavior that diverges from adult behavior. In the second condition of van de Walle et al. (2000) and Xu and Carey (1996), in which the featurally different objects were only visible sequentially, 10-month-old children showed behavior that was different from that predicted for adults. Diverging behavior could serve as a hint that children perceive the world in terms of a different ontology. Apparently, given the initial featural situation, that is, the perceived pattern of features, their expectations regarding the regularity of feature changes are different.

However, from a feature processing perspective, younger infants do not seem to base their expectations on all relevant correlated features, because they have not had the opportunity to acquire knowledge of certain feature interactions. Infants may build up expectations based on already experienced regularities of specific feature-interactions—such as occlusion, containment, collision, and the like. Only infants who have already acquired feature-based knowledge of such regularities can expect certain interactions between features and draw conclusions about which feature changes are likely to occur in which interactions and which are not. This is to say that expectations do not only depend on the ability to detect certain kinds of features, but they also depend on acquired knowledge of certain kinds of *feature interactions*.

The developmental shift between 10- and 12-month-olds in the second condition of the experiments of van de Walle et al. (2000) and Xu and Carey (1996) can correspondingly be explained in terms of familiarity with different kinds of feature interactions, that is, based on

features alone (see also Mendes, Rakoczy & Call, 2008). So deviations from adult behavior are likely to result from infants' familiarity with certain kinds of feature interactions and not with others. While a feature is seen as relevant in one feature interaction, the same feature is not taken as relevant in another feature interaction.

4.3 | Revisiting Yoon et al. (2008)

The results of the experiments by Yoon et al. (2008) and Hernik et al. (2018) seem surprising compared to what we would expect. In the pointed-at/ostensive communication condition (even if the position of the pointed-at object is highly relevant, Hernik et al., 2018), children seem to be locked into a featural interpretation. In a reach-for situation, however, children take into account what we would generally call "position of the object". This may indicate an ontological difference—that children do not react based on object reference but use information as pertaining to the object's features. The authors nonetheless interpret the results according to the object-first hypothesis: Children understand the reaching gestures as referring to the position of the object in the reaching-for condition, while they inhibit this ability in the pointed-at/ostensive-communication condition and interpret the pointing in combination with verbal ostensive information as referring to a feature.

For an alternative explanation, let us continue to assume that young children are feature-placers. For feature-placers, pointing in combination with ostensive verbal information by adults might be understood in terms of combined visual and auditory cues highlighting a particular section of a feature pattern. The pointing gesture draws attention to a confined section of a feature pattern, while a reaching gesture—due to the goal underlying the movement—highlights distance to the reaching subject which, for feature placers, is operationalized as a feature-section within a broader featural pattern. To see how distance can be tracked by feature placers, without having to represent space or objects, consider Gibson's (1988, 1995) description of how infants learn to react appropriately to an approaching object. Gibson pointed out that movement of an observer necessarily results "in optical motion of a deforming character (e.g., expansion or contraction) over the total optical array, while motion of an object in the layout results in a local displacement relative to its background" (Gibson, 1995, p. xxxvii). For example, an approaching object at a very short distance would produce the impression of a quickly expanding, cohesive feature pattern: The filling of the entire visual field with a solid plane. Changes of distance between objects would appear as changes of feature sections within a broader featural pattern.

In summary, according to this interpretation of the Yoon et al. (2008) experiments, children can interpret what each gesture highlights in terms of features alone. Depending on the gesture that is used, the relevant feature section differs. Note again that feature-placers can detect differences in feature patterns that we perceive as differences in the location of an object within our ontology. A similar line of argument can apply to differences in quantity.

4.4 | Summary

Current research on object individuation attempts to show that infants can individuate objects just like adults. However, we have discussed general difficulties in attributing ontologies to human subjects who are dissimilar to adults, and the availability of alternative explanations

questions this strategy of imposing our ontology onto beings that need not share it. Instead of taking infants' adult-like behavior as proof for their having the same ontology as adults, alternative ontologies that can explain the experimental findings should be seriously considered, and infants' behavior should be interpreted carefully. The discussion above suggests that infants' success in individuation tasks need not show that they can indeed individuate objects. Infants' correct performance might equally well rely on their experience with event-specific feature interactions. Feature interactions can, in general, be accessed via feature-based reasoning.

Furthermore, infant behavior that differs from adult behavior in individuation tasks can suggest that infants may not individuate objects. Differences in behavior are indicative of ontological differences because any subject who can individuate objects must be able to reliably infer the correct number of objects involved in the above occlusion events, regardless of the features that are involved. Being able to individuate objects involves an understanding of locations and objects as being either the same or different, that is, an understanding of identity. Being able to use spatiotemporal information in forming expectations about the course of events ensures reliable success in individuation tasks. Subjects who are not able to individuate objects, on the other hand, must rely on specific information about features and feature-interactions and might fail to form appropriate expectations when confronted with unfamiliar patterns. Being able to individuate objects provides a principle-based approach to the situation at hand and alleviates the restriction to known types of feature interactions.

Additionally, we can conclude from the discussion above that infants' inability to encode position in ostensive pointing tasks can hint at infants' inability to individuate objects. At the same time, infants' success in such tasks would not provide reliable evidence that they can individuate objects. If an agent cannot individuate objects, she cannot understand information about individual objects either. Reference to particulars is associated with individuating objects.

We propose that the object-first interpretation of the findings discussed above is not the only viable interpretation. In the light of theoretical and computational considerations, it appears to be an unnecessarily strong interpretation. In summary, analytic and linguistic considerations show that reference to objects may be cognitively more demanding than the discrimination of features and feature interactions. Computational models demonstrate that patterns of behavior that are analogous to those observed in infants can be produced without basing algorithms on object individuation at all. Attributing high-level cognitive capacities when the empirical evidence only provides evidence for some aspects of these capacities is problematic for reasons of parsimony, especially in the context of infant research. What is needed to provide evidence for infants' object individuation capacities are principled expectations to the effect "that certain ontological schemes are more likely than others to support certain kinds of expectations" (Hirsch, 1997).

5 | PRINCIPLE-BASED EMPIRICAL EXPECTATIONS FOR AN ONTOLOGY WITHOUT OBJECTS

While we reject standard interpretations of the studies discussed above for being inconclusive concerning infants' actual ontological commitments, we do not propose that children's ontologies are fundamentally inaccessible. On the contrary, children who cannot individuate objects should differ from children who have already acquired this ability, among other things, in the following two crucial ways.

5.1 | Markers for object individuation I: Using an object's history

Infants who cannot individuate objects do not understand episodic information, that is, information concerning a single object, and *a fortiori* cannot use an object's history to individuate that object. The history of an object provides episodic information that adults use consistently to individuate objects.

During an experiment, an object could be introduced as having a special history by highlighting it in a set of featurally indistinguishable objects via (a) its spatiotemporal origin (e.g., it comes from and belongs in a different container than the others); (b) the role it had in different play situations (e.g., it was passed back and forth between child and an experimenter (E); (c) what happened to it during a shared interaction (e.g., it was dropped from the table and had to be retrieved by E and the child); (d) the child's own interaction with it (e.g., it is the only one the child actually touched or placed herself); (e) a change in ownership (e.g., it is presented to the child as a gift). Using such manipulations, an object may be established as having a unique history with that infant, which could single it out relative to a set of featurally indistinguishable objects. At test, infants would then be requested to choose the object with a unique history from an array of featurally indistinguishable objects.

In principle, even such historic individuation of objects could be mimicked by feature placing infants. However, following our interpretation of the experiments conducted by Yoon et al. (2008), attempts to historically single out an object strongly highlight a relatively confined feature pattern as relevant, just like pointing gestures and verbal cues. Thus, it would be expected that these interactions similarly confine the area of the presented feature pattern so that the overall pattern of feature changes cannot be used to detect differences in the history of an object (Yoon et al., 2008). The differences in the overall featural pattern then lie outside of the confined feature pattern that was highlighted. As a result, children without the ability to individuate objects should not be able to re-identify an object from an array of featurally indistinguishable objects based on its history—even if the object was not occluded at any time. Correspondingly, featurally indistinguishable objects which are ostensively highlighted can only be individuated by subjects who are able to use objects' histories, that is, episodic information.

5.2 | Markers for object individuation II: Avoiding errors of misidentification

In situations where feature-based individuation is difficult or impossible, only spatiotemporal history can be used to single out an individual. Children who are aware of this problem should take precautions to avoid situations in which spatiotemporal information is not available. An agent who is able to individuate objects and who is motivated to keep one particular object in possession should try to avoid confusing it with another object.

An experimental situation could be created in which a child runs the risk of confusing an object they would like to keep separate from a set of featurally indistinguishable objects. The procedure might require the children to briefly give up the object that is special to them and place it in a container with other identical items. From familiarization trials, children might have learned that the container will be shaken or spun and, hence, they might be motivated to take precautions against confusing the objects. At test, children could then be confronted with two containers. In one container, their special object would be directly placed among identical objects. In the second container, a barrier in the middle would allow placing the special one

and its replicas in different compartments. Children who are able to individuate objects should prefer the container with different compartments over the unsegmented one. Children who do not individuate objects should not make any attempts to avoid such confusion and choose randomly. Overall, in order to test for ontological differences, it is crucial to find experimental setups in which featural information cannot be used to produce behavior that is equivalent to behavior based on object individuation.

6 | CONCLUSION

The main aim of this article was to highlight that the widespread claim that young infants individuate objects may overestimate their cognitive abilities. We presented analytic considerations that show that individuation is more demanding than often assumed, emphasizing the importance of the acquisition of a concept of identity via indexicals for developing the capability to individuate. Furthermore, we summarized the general critiques of the object-first interpretation and presented information processing accounts (Cohen et al., 2002) as an alternative. We developed more parsimonious interpretations of some paradigmatic object-first studies and concluded with a suggestion for experimental protocols that cannot be solved by an agent relying on feature-discrimination alone. Such experiments may provide a strong test for possible ontological differences between agents who are feature placers and those who can individuate objects. We claimed that the "referential side" of triangulation (child-object)—its mechanics and impact on individuation skills—could be investigated by focusing on whether infants are able to reidentify an object via its history in an array of featurally indiscriminable objects. Children's motivation to avoid errors of misidentification would be a strong indicator of their ability to individuate objects.

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REFERENCES

Aguiar, A. & Baillargeon, R. (1999). 2.5-month-old infants' reasoning about when objects should and should not be occluded. *Cognitive Psychology*, *39*(2), 116–157. https://doi.org/10.1006/cogp.1999.0717

Anderson, S. R. & Keenan, E. (1985). Deixis. In T. Shopen (Ed.), *Language typology and syntactic description Grammatical categories and the lexicon* (Vol. 3, pp. 259–308). Cambridge, MA: Cambridge University Press.

Baillargeon, R. (1986). Representing the existence and the location of hidden objects: Object permanence in 6-and 8-month-old infants. *Cognition*, *23*(1), 21–41. https://doi.org/10.1016/0010-0277(86)90052-1

Baillargeon, R. (1987). Object permanence in 3.5- and 4.5-month-old infants. *Developmental Psychology*, *23*(5), 655–664. https://doi.org/10.1037/0012-1649.23.5.655

Baldwin, D. A. & Moses, L. J. (2001). Links between social understanding and early word learning: Challenges to current accounts. *Social Development*, *10*(3), 309–329. https://doi.org/10.1111/1467-9507.00168

Blok, S., Newman, G. & Rips, L. J. (2005). Individuals and their concepts. In W.-K. Ahn, R. L. Goldstone, B. C. Love, A. B. Markman & P. Wolss (Eds.), *APA decade of behavior series. Categorization inside and outside the laboratory: Essays in honor of Douglas L. Medin* (pp. 127–149). Washington, DC: American Psychological Association. https://doi.org/10.1037/11156-008

Cacchione, T. & Rakoczy, H. (2017). Comparative metaphysics: Thinking about objects in space and time. In J. Call, G. M. Burghardt, I. M. Pepperberg, C. T. Snowdon & T. Zentall (Eds.), *Handbook of comparative psychology volume 2: Perception, learning and cognition* (pp. 579–599). Washington, DC: American Psychological Association.

Campbell, J. (2002). *Reference and consciousness*. Oxford: Oxford University Press.

Carey, S. (2002). Evidence for numerical abilities in young infants: A fatal flaw? *Developmental Science*, *5*(2), 202–205. https://doi.org/10.1111/1467-7687.00221_1

Carey, S. (2009). *The origin of concepts*. Oxford: Oxford University Press.

Castañeda, H.-N. (1966). "He": A study in the logic of self-consciousness. *Ratio*, *8*, 130–157.

Castañeda, H.-N. (1968). On the logic of attributions of self-knowledge to others. *Journal of Philosophy*, *65*(15), 439–456.

Chomsky, N. (2000). *New horizons in the study of language and mind*. Cambridge, MA: Cambridge University Press.

Clark, E. V. & Sengul, C. J. (1978). Strategies in the acquisition of deixis. *Journal of Child Language*, *5*(3), 457–475. https://doi.org/10.1017/S0305000900002099

Cohen, L. B. & Cashon, C. H. (2001). Infant object segregation implies information integration. *Journal of Experimental Child Psychology*, *78*(1), 75–83. https://doi.org/10.1006/jecp.2000.2602

Cohen, L. B., Chaput, H. H. & Cashon, C. H. (2002). A constructivist model of infant cognition. *Cognitive Development*, *17*(3–4), 1323–1343. https://doi.org/10.1016/S0885-2014(02)00124-7

Cohen, L. B. & Marks, K. S. (2002). How infants process addition and subtraction events. *Developmental Science*, *5*(2), 186–201. https://doi.org/10.1111/1467-7687.00220

Cohen, L. B. & Younger, B. A. (1984). Infant perception of angular relations. *Infant Behavior and Development*, *7*(1), 37–47. https://doi.org/10.1016/S0163-6383(84)80021-1

Csibra, G. & Gergely, G. (2009). Natural pedagogy. *Trends in Cognitive Science*, *13*(4), 148–153. https://doi.org/10.1016/j.tics.2009.01.005

Csibra, G. & Shamsudheen, R. (2015). Nonverbal generics: Human infants interpret objects as symbols of object kinds. *Annual Review of Psychology*, *66*, 689–710. https://doi.org/10.1146/annurev-psych-010814-015232

Diessel, H. (2006). Demonstratives, joint attention, and the emergence of grammar. *Cognitive Linguistics*, *17*(4), 463–489. https://doi.org/10.1515/COG.2006.015

Diessel, H. (2014). Demonstratives, frames of reference, and semantic universals of space. *Language and Linguistics Compass*, *8*(3), 116–132. https://doi.org/10.1111/lnc3.12066

Donnellan, K. S. (1966). Reference and definite descriptions. *The Philosophical Review*, *75*(3), 281–304. https://doi.org/10.2307/2183143

Evans, G. (1982). *The varieties of reference*. Oxford: Clarendon Press.

Frege, G. (1892). Über sinn und bedeutung. *Zeitschrift für Philosophie Und Philosophische Kritik*, *100*(1), 25–50.

Gibson, E. J. (1988). Exploratory behavior in the development of perceiving, acting, and the acquiring of knowledge. *Annual Review of Psychology*, *39*(1), 1–42. https://doi.org/10.1146/annurev.ps.39.020188.000245

Gibson, E. J. (1995). Exploratory behavior in the development of perceiving, acting, and the acquisition of knowledge. In C. Rovee-Collier & L. P. Lipsitt (Eds.), *Advances in infancy research* (Vol. 9, pp. xxi–lxi). Norwood, NJ: Ablex Publishing.

Gliga, T. & Csibra, G. (2009). One-year-old infants appreciate the referential nature of deictic gestures and words. *Psychological Science*, *20*(3), 347–353. https://doi.org/10.1111/j.1467-9280.2009.02295.x

Haith, M. M. (1998). Who put the cog in infant cognition? Is rich interpretation too costly? *Infant Behavior and Development*, *21*(2), 167–179. https://doi.org/10.1016/S0163-6383(98)90001-7

Hernik, M., Sperber, D. & Gergely, G. (2018, January). *Infants' encoding of location and appearance of pointed-at and reached-for objects when both location and appearance are relevant*. Poster presented at the Budapest CEU conference on cognitive development 2018, Budapest.

Hinzen, W. & Sheehan, M. (2015). *The philosophy of universal grammar*. Oxford: Oxford University Press.

Hirsch, E. (1997). Basic objects: A reply to Xu. *Mind & Language*, *12*(3–4), 406–412. https://doi.org/10.1111/1468-0017.00054

Hume, D. (1978). *A treatise on human nature*. Oxford: Oxford University Press.

Johnson, S. P. (2009). Perceptual completion in infancy. In S. P. Johnson (Ed.), *Neoconstructivism: The new science of cognitive development* (pp. 45–60). Oxford: Oxford University Press.

Kagan, J. (2008). In defense of qualitative changes in development. *Child Development*, *79*(6), 1606–1624. https://doi.org/10.1111/j.1467-8624.2008.01211.x

Kahneman, D., Treisman, A. & Gibbs, B. J. (1992). The reviewing of object files: Object-specific integration of information. *Cognitive Psychology*, *24*(2), 175–219. https://doi.org/10.1016/0010-0285(92)90007-O

Kaplan, D. (1979). On the logic of demonstratives. *Journal of Philosophical Logic*, *8*(1), 81–98.

Kripke, S. A. (1980). *Naming and necessity*. Cambridge, MA: Harvard University Press.

Krizhevsky, A., Sutskever, I. & Hinton, G. E. (2012). ImageNet classification with deep convolutional neural networks. In F. Pereira, C. J. C. Burges, L. Bottou & K. Q. Weinberger (Eds.), *Advances in neural information processing systems 25* (pp. 1097–1105). Red Hook, NY: Curran Associates, Inc..

Krøjgaard, P. (2004). A review of object individuation in infancy. *British Journal of Developmental Psychology*, *22*(2), 159–183. https://doi.org/10.1348/026151004323044555

Leung, S., Mareschal, D., Rowsell, R., Simpson, D., Iaria, L., Grbic, A. & Kaufman, J. (2016). Oscillatory activity in the infant brain and the representation of small numbers. *Frontiers in Systems Neuroscience*, *10*, 4. https://doi.org/10.3389/fnsys.2016.00004

Lotter, W., Kreiman, G. & Cox, D. D. (2016). Deep predictive coding networks for video prediction and unsupervised learning. Retrieved from: http://arxiv.org/abs/1605.08104.

Lovett, A. & Scassellati, B. (2004). *Using a robot to reexamine looking time experiments*. Paper presented at the fourth international conference on development and learning, San Diego, CA.

Lycan, W. G. (2008). *Philosophy of language: A contemporary introduction* (2nd ed.). New York, NY: Routledge.

Mandler, J. M. (1992). Commentary. *Human Development*, *35*(4), 246–253. https://doi.org/10.1159/000277172

Mareschal, D., Plunkett, K. & Harris, P. (1999). A computational and neuropsychological account of object-oriented behaviours in infancy. *Developmental Science*, *2*(3), 306–317. https://doi.org/10.1111/1467-7687.00076

Martin, T. & Hinzen, W. (2014). The grammar of the essential indexical. *Lingua*, *148*, 95–117. https://doi.org/10.1016/j.lingua.2014.05.016

Mattos, O. & Hinzen, W. (2015). The linguistic roots of natural pedagogy. *Frontiers in Psychology*, *6*, 1424. https://doi.org/10.3389/fpsyg.2015.01424

Mendes, N., Rakoczy, H. & Call, J. (2008). Ape metaphysics: Object individuation without language. *Cognition*, *106*(2), 730–749. https://doi.org/10.1016/j.cognition.2007.04.007

Mill, J. S. (2012). *A system of logic, ratiocinative and inductive: Being a connected view of the principles of evidence, and the methods of scientific investigation* (Vol. 1, p. 1843). New York, NY: Cambridge University Press.

Moore, K. & Meltzoff, A. (2009). Numerical identity and the development of object permanence. In S. P. Johnson (Ed.), *Neoconstructivism: The new science of cognitive development* (pp. 61–83). New York, NY: Oxford University Press.

Moore, M. K. & Meltzoff, A. N. (1999). New findings on object permanence: A developmental difference between two types of occlusion. *British Journal of Developmental Psychology*, *17*(4), 623–644. https://doi.org/10.1348/026151099165410

Munakata, Y. (1998). Infant perseveration and implications for object permanence theories: A PDP model of the AB task. *Developmental Science*, *1*(2), 161–184. https://doi.org/10.1111/1467-7687.00021

Munakata, Y., McClelland, J. L., Johnson, M. H. & Siegler, R. S. (1997). Rethinking infant knowledge: Toward an adaptive process account of successes and failures in object permanence tasks. *Psychological Review*, *104*(4), 686–713. https://doi.org/10.1037/0033-295X.104.4.686

Needham, A. (2001). Object recognition and object segregation in 4.5-month-old infants. *Journal of Experimental Child Psychology*, *78*(1), 3–24. https://doi.org/10.1006/jecp.2000.2598

Needham, A. & Baillargeon, R. (1998). Effects of prior experience on 4.5-month old infants' object segregation. *Infant Behavior and Development*, *21*(1), 1–24. https://doi.org/10.1016/S0163-6383(98)90052-2

Outler, A. C. (2006). Augustine: *Confessions*. In A. C. Outler (Ed.), *Confessions and Enchiridion* (pp. 397–400). Louisville: Westminster John Knox.

Peeters, D. & Özyürek, A. (2016). "This" and "that" revisited: A social and multimodal approach to spatial demonstratives. *Frontiers in Psychology*, *7*, 222. https://doi.org/10.3389/fpsyg.2016.00222

Perry, J. (2000). *The problem of the essential indexical and other essays* (Expanded ed.). Stanford, CA: CSLI Publications.

Piaget, J. (1953). *The origins of intelligence in children*. London: Routledge & Kegan Paul.

Piaget, J. (1954). *The construction of reality in the child*. New York, NY: Basic Books. https://doi.org/10.1037/11168-000

Pietroski, P. O. (2018). *Conjoining meanings: Semantics without truth values*. Oxford: Oxford University Press. https://doi.org/10.1093/oso/9780198812722.001.000

Pylyshyn, Z. W. (2001). Visual indexes, preconceptual objects, and situated vision. *Cognition*, *80*(1–2), 127–158. https://doi.org/10.1016/S0010-0277(00)00156-6

Quine, W. V. O. (1960). *Word and object*. Cambridge, MA: MIT Press.

Redmon, J. & Farhadi, A. (2017). YOLO9000: Better, faster, stronger. In *2017 IEEE conference on computer vision and pattern recognition (CVPR)* (pp. 6517–6525). Honolulu, HI: IEEE. https://doi.org/10.1109/CVPR.2017.690

Russell, B. (1905). On denoting. *Mind*, *14*(56), 479–493. http://www.jstor.org/stable/2248381

Schlesinger, M. (2003). A lesson from robotics: Modeling infants as autonomous agents. *Adaptive Behavior*, *11*(2), 97–107. https://doi.org/10.1177/10597123030112003

Schöner, G. & Thelen, E. (2006). Using dynamic field theory to rethink infant habituation. *Psychological Review*, *113*(2), 273–299.

Searle, J. R. (1958). Proper names. *Mind*, *67*(266), 166–173.

Sheehan, M. & Hinzen, W. (2011). Moving towards the edge: The grammar of reference. *Linguistic Analysis*, *37*(3–4), 405–458. https://doi.org/10.1023/A:1009780124314

Sobel, D. M. (2009). Integrating top-down and bottom-up approaches to children's causal inference. In S. P. Johnson (Ed.), *Neoconstructivism: The new science of cognitive development* (pp. 159–179). New York, NY: Oxford University Press.

Speaks, J. (2019). Theories of meaning. In E. N. Zalta (Ed.), *The Stanford encyclopedia of philosophy* (Fall 2019 ed.). Stanford, CA: Stanford University Press Retrieved from https://plato.stanford.edu/archives/fall2019/entries/meaning/

Spelke, E. S., Kestenbaum, R., Simons, D. J. & Wein, D. (1995). Spatiotemporal continuity, smoothness of motion and object identity in infancy. *British Journal of Developmental Psychology*, *13*(2), 113–142. https://doi.org/10.1111/j.2044-835X.1995.tb00669.x

Strawson, P. F. (1959). *Individuals*. London: Methuen.

Thelen, E., Schöner, G., Scheier, C. & Smith, L. B. (2001). The dynamics of embodiment: A field theory of infant perseverative reaching. *The Behavioral and Brain Sciences*, *24*(1), 1–34.

Tomasello, M. (2010). *Origins of human communication*. Cambridge: MIT press.

Tomasello, M. & Carpenter, M. (2007). Shared intentionality. *Developmental Science*, *10*(1), 121–125. https://doi.org/10.1111/j.1467-7687.2007.00573.x

Tomasello, M., Carpenter, M. & Liszkowski, U. (2007). A new look at infant pointing. *Child Development*, *78*(3), 705–722. https://doi.org/10.1111/j.1467-8624.2007.01025.x

Tremoulet, P. D., Leslie, A. M. & Hall, D. G. (2000). Infant individuation and identification of objects. *Cognitive Development*, *15*(4), 499–522. https://doi.org/10.1016/S0885-2014(01)00038-7

Tugendhat, E. (1976). Einführung in die sprachanalytische Philosophie. Frankfurt am Main: Suhrkamp. [English translation: Tugendhat, E. (2016), Traditional and analytical philosophy: Lectures on the philosophy of language. Cambridge, MA: Cambridge University Press. https://doi.org/10.1017/CBO9781316535608]

van de Walle, G. A., Carey, S. & Prevor, M. (2000). Bases for object individuation in infancy: Evidence from manual search. *Journal of Cognition and Development*, *1*(3), 249–280. https://doi.org/10.1207/S15327647JCD0103_1

Wilcox, T. & Baillargeon, R. (1998). Object individuation in young infants: Further evidence with an event-monitoring paradigm. *Developmental Science*, *1*(1), 127–142. https://doi.org/10.1111/1467-7687.00019

Wittgenstein, L. (1969). *On certainty*. Oxford: Basil Blackwell.

Wynn, K. (1992). Addition and subtraction by human infants. *Nature*, *358*(6389), 749–750. https://doi.org/10.1038/358749a0

Wynn, K. (2002). Do infants have numerical expectations or just perceptual preferences? *Developmental Science*, *5*(2), 207–209. https://doi.org/10.1111/1467-7687.00221_3

Xu, F. (2007). Sortal concepts, object individuation, and language. *Trends in Cognitive Sciences*, *11*(9), 400–406. https://doi.org/10.1016/j.tics.2007.08.002

Xu, F. & Carey, S. (1996). Infants' metaphysics: The case of numerical identity. *Cognitive Psychology*, *30*(2), 111–153. https://doi.org/10.1006/cogp.1996.0005

Xu, F., Carey, S. & Quint, N. (2004). The emergence of kind-based object individuation in infancy. *Cognitive Psychology*, *49*(2), 155–190. https://doi.org/10.1016/j.cogpsych.2004.01.001

Xu, F., Cote, M. & Baker, A. (2005). Labeling guides object individuation in 12-month-old infants. *Psychological Science*, *16*(5), 372–377. https://doi.org/10.1111/j.0956-7976.2005.01543.x

Yoon, J. M., Johnson, M. H. & Csibra, G. (2008). Communication-induced memory biases in preverbal infants. *Proceedings of the National Academy of Sciences*, *105*(36), 13690–13695. https://doi.org/10.1073/pnas.0804388105

Younger, B. A. & Cohen, L. B. (1983). Infant perception of correlations among attributes. *Child Development*, *54*(4), 858 https://doi.org/10.2307/1129890

Younger, B. A. & Cohen, L. B. (1986). Developmental change in infants' perception of correlations among attributes. *Child Development*, *57*(3), 803–815. https://doi.org/10.2307/1130356

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