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Object Individuation in the Absence of Kind-specific Surface Features: Evidence for a Primordial Essentialist Stance?

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ABSTRACT

It has been suggested that due to functional similarity, sortal object individuation might be a primordial form of psychological essentialism. For example, the relative independence of identity judgment from perceived surface features is a characteristic of essentialist reasoning. Also, infants engaging in sortal object individuation pay more attention to kind than surface feature information when judging the identity of objects (e.g.). Indeed, previous research found that 14-month-old infants can judge trans-temporal identity even in complete absence of kind-specific surface features. Here, we used another more demanding non-linguistic paradigm to test the limits of these abilities in 14-, 18-, 23- and 36-month-old infants, comparing their performance to recent great ape data. Particularly, we presented infants with two food kinds, whose surface features were then fully transformed to make them look identical. If reasoning according to essentialist principles, participants should select the preferred item despite superficial manipulations. However, only 36-month-olds reliably tracked the preferred item after superficial manipulations. This suggests that, although basic psychological essentialism may emerge early in infancy, more complex forms require domain-general cognitive prerequisites, which only develop in more protracted form.

Introduction

Human adults are psychological essentialists (Gelman, 2003; Keil, 1989). In its broadest sense, essentialism characterizes the specific nature of our cognitive access to the structure of objects and categories in the world. People engage in essentialism when reflecting on the identity of natural kinds (e.g., “diamonds” or “lions”). From an essentialist perspective, natural kinds have two levels of properties: a level of deep essential properties (defining the kind and identity of objects, like chemical or biological properties) and a level of characteristic surface features (which may be changed without altering the identity of objects). Although humans are largely ignorant about what exactly these essential properties are (Kripke, 1972; Medin & Ortony, 1989; Putnam, 1975), they are usually assumed to lie deep within the objects, be superficially invisible but causally related to surface properties (e.g., tigers look like tigers because of their tiger-hood; Gelman & Wellman, 1991; Gottfried & Gelman, 2005).

From around 4 years of age, children’s reasoning reflects psychological essentialism (see Gelman, 2003; Keil, 1982). In category-based induction tasks, for instance, children transfer

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invisible essential properties among objects of the same kind, in the face of different superficial features (Gelman & Markman, 1986, 1987; Keil, 1989). For example, children infer that sharks breathe like fish and not like dolphins, because sharks are fish, despite being more similar to dolphins (Gelman & Markman, 1986). Moreover, they also understand that raccoons remain raccoons, even if they are painted and superficially look like squirrels (Keil, 1989).

Traditionally, researchers have used linguistic paradigms to explore psychological essentialism, so that little has been known about its ontogenetic and phylogenetic roots in preverbal infants and nonverbal animals. However, psychological essentialism may develop gradually, and some basic forms may already be present in early infancy or across other species. While it is likely that complex essentialist thought (e.g. understanding the causal relatedness of essential and accidental object properties) is only present in older children and adults, basic intuitions about the identity and stability of objects belonging to a given kind may be ontogenetically and phylogenetically more common (Rakoczy & Cacchione, 2014, 2018) than previously thought (Fodor, 1998). Specifically, sortal object individuation – the ability to keep track and re-identify objects over time on the basis of sortal concepts – may be viewed as a primordial form of psychological essentialism potentially present earlier in development or in other species (Rakoczy & Cacchione, 2014, 2018; Xu & Carey, 1996). A recent proposal suggests, for example, that kind-based representations and a notion of agentive causality are the cognitive precursors from the combination of which a full biological essentialist theory emerges later in development (Taborda-Osorio & Cheries, 2017).

In the philosophical literature, the term "sortal" refers to concepts that provide criteria for individuation and identity (e.g., Macnamara, 1987; Wiggins, 1967). Using sortal concepts (typically lexicalized as count nouns), people can answer questions of individuation and identity such as "How many x are here?" or "Is this the same x as I saw a minute ago?" In contrast, non-sortal concepts (e.g., "being red") would not be helpful in this respect. We suggest that sortal object individuation may be viewed as a basic form of psychological essentialism, because it shares some of the central signatures of psychological essentialism and satisfies similar cognitive functions (Rakoczy & Cacchione, 2018). Particularly, sortal object individuation also serves as a tool for dealing with problems of identity, and allows to distinguish between essential (persisting) and accidental (potentially changing) surface properties which is crucial to psychological essentialism.

Non-linguistic experimental approaches allowed testing for sortal object individuation in preverbal infants and nonverbal animals, showing that the ability to distinguish between essential (kind) properties and accidental features may indeed be present in infants and non-human primates. In a typical test, participants see an object of kind 1 (e.g., a bunny) disappear in a box and can then search the box for the object (e.g., Xu & Baker, 2005). When searching, participants can either find an object of the same kind 1 or (unexpectedly) an object of a different kind 2 (e.g., a carrot). Infants from around 12 months (Krøjgaard, 2004; Van de Walle, Carey, & Prevor, 2000; Xu & Baker, 2005; Xu, Carey, & Quint, 2004) and non-human primates (Mendes, Rakoczy, & Call, 2008, 2011; Phillips & Santos, 2007; Santos, Sulkowski, Spaepen, & Hauser, 2002) search significantly longer after first finding the unexpected object, suggesting that they detect the category change and expect to find the missing object in the box.

Infant research on object individuation using such non-linguistic methodology shows that the capacity to individuate objects by featural/kind information (around 10–12 months; Kingo & Krøjgaard, 2011; Taborda-Osorio & Cheries, 2018; Xu et al., 2004) emerges much later than individuating by spatiotemporal information (as early as around 2 months; Aguiar & Baillargeon, 1999; Spelke, Kestenbaum, Simons, & Wein, 1995; Wynn, 1992; Xu & Carey, 1996). The *emerging kind representation hypothesis* holds that this developmental step does not reflect the acquisition of increased processing skills apt to deal with richer information (Xu et al., 2004). Instead, it suggests that the ability to represent kinds is itself a necessary prerequisite to engage in more elaborate forms of identity judgment. Xu et al. (2004) showed that while infants referred to kind information in object individuation tasks, they failed to individuate objects by featural information alone, especially in situations where features were not importantly correlated to kind-membership (e.g., in within-kind comparison). Moreover, research showed that infants' selection of specific features to individuate objects was a function of their kind representations, e.g. only those features were considered informative regarding kind membership (e.g., form aspects in case of between-kind comparisons). The somewhat counterintuitive conclusion to be drawn from this research is that by 12 months of ages processing kinds is more fundamental to trans-temporal identity judgment than processing surface appearance.

The relationship between featural and kind information in the individuation process is very complex but can be well explained by the theory-based view of concept formation. The theory-based view of concept formation suggests that the features associated with a kind are not available as a list of independent features, but that there are concept-based theoretical assumptions about how these features are causally connected (e.g., Rehder, 2017). This account is in contrast to the view that infants categorize simply on the basis of perceived similarity (i.e., surface appearance), and may explain why infants rely on some features but disregard of others when individuating objects. Using a concept, infants do not have to consider all potential properties (of a list) but may use the presence of some properties as an indicator to infer the presence of other (possibly invisible) properties. Features are therefore only relevant as far as they signal the underlying kind, which in turn informs about other (potentially hidden) properties to be expected. Moreover, surface features vary in their explanatory value for kind membership and are therefore considered to be of different relevance (e.g., shape is often more informative about kind membership than color and is, therefore, more likely to be considered by infants, see, e.g.,, Xu et al., 2004). Infants engaging in sortal object individuation, therefore, rely on non-visible properties in at least two ways. First, identity judgments include generic (theoretical) information not directly present in the local situation (e.g., properties that an object of kind x usually has). Second, identity judgments refer to internal properties of objects that are not perceptible on the surface (e.g., deep inner properties). Engaging in sortal object individuation thus means going beyond information that is directly visible in a given situation and referring to stored conceptual information about kinds.

In a nutshell, according to this view, theoretical-causal knowledge trumps surface appearance in infants' sortal object individuation. Infants have conceptual assumptions regarding the relatedness of features and their relative importance to object identity, considering single properties depending on their significance to object identity. The relatedness of these early abilities to psychological essentialism is obvious; all these principles apply under an essentialist perspective: An essentialist approach considers surface features as signals to a hidden essence and assumes causal relatedness between non-visible essential and visible surface properties, thereby going beyond what is seen at the outside of objects. However, essentialist reasoning might be more radically independent of surface appearance than these early manifestations of sortal object individuation. In fact, from an essentialist perspective, it is possible to assume a stable identity/kind membership across transformation even in absence of kind-specific surface features, provided the entity in question was represented as a token of this specific kind before the transformation. For example, under an essentialist perspective, a raccoon remains a raccoon, even if it is transformed to look in every single surface feature identically as another kind (e.g., a skunk), as long as the perceiver represented the entity as a raccoon before the transformation (Keil, 1989). Based on previous infant research, it cannot be decided whether sortal object individuation is equally independent of external features as demonstrated for essentialism. Unlike the research on psychological essentialism, research on the development of sortal individuation did not investigate trans-temporal identity judgments in absence of kind-relevant surface feature differences. In the above-mentioned search paradigm, for example, information about kinds (essential properties) and information about surface properties are usually confounded (e.g., balls and cups are different kinds of objects, but they also *look* very different), and success in this task could be achieved by tracking superficial rather than hidden (essential) properties. Even in the tasks of Xu et al. (2004), kind differences were usually accompanied by one kind-relevant surface feature difference (e.g., shape differences).

Cacchione, Schaub, and Rakoczy (2013), therefore, implemented a protocol combining the logic of individuation studies with that of verbal transformation studies, fully disentangling the impact of kind information (essential properties) and superficial feature information on participants' identity judgments. In this study, 14-month-olds were tested with dual-aspect-toys which could be turned inside out, thus having two different types of appearances, A and B (e.g., look either like a bunny or a carrot). In the test, infants saw the toy enter the box with appearance A (e.g., bunny surface) and they retrieved the toy from the box either with the same appearance A or with a different appearance B (e.g., carrot surface). The dependent measure was whether infants would go on searching for a "missing" object. Crucially, half of the 14-month-olds were previously familiarized with dual-aspect toys and shown the turning mechanism, whereas the other half remained naïve. While the naïve infants interpreted the difference in appearance as an indication of identity change (searching longer when the toy retrieved looked different from the one inserted in the box), the familiarized infants considered the bunny and the carrot to be the same object, and did not search for another object. Therefore, infants did not simply rely on superficial features to individuate objects, but distinguished between those superficial transformations that were diagnostic of identity changes and those that were not (Cacchione et al., 2013). This might be viewed as the first evidence that human infants are capable of true sortal object individuation and that their identity judgments are similarly independent of perceived surface properties, as was demonstrated for psychological essentialism. Along similar lines, from about13 months of age, infants treat inner properties as more relevant than external properties when individuating self-propelled agents (Newman, Herrmann, Wynn, & Keil, 2008; Taborda-Osorio & Cheries, 2018). Together, this provides evidence that sortal object individuation shares the major cognitive aspects of essentialism and may thus be considered an early form of essentialist reasoning.

From a comparative point of view, a similar approach has also been used in non-human primates. Cacchione, Hrubesch, Call, and Rakoczy (2016) investigated sortal object individuation in great apes, including tasks of different type and difficulty level. Crucially, one series of choice tasks including more extensive transformations tested apes' abilities to judge identity/kind membership in the absence of kind-specific surface features (Cacchione et al., 2016). Apes were presented with two items of two different kinds and had to simultaneously track the items through surface transformations (e.g., carrots were transformed into banana-looking items and vice versa). The question was whether apes would successfully identify their preferred item (e.g., the banana item), suggesting that they are able to disentangle the true kind membership from the potentially misleading appearance. These tasks proved to be rather demanding for the apes, posing great executive and representational challenges (as they had to build and compare past and present models of two different food kinds). Only with high motivational incentives (e.g., big stimuli), they could manage to deal with the most complex conditions, while conditions with reduced processing demands (e.g., conditions involving only one food kind) were solved comparatively well.

Overall, these results showed that great apes are able to individuate objects on the basis of sortal information, even in the presence of misleading surface feature information. This suggests that apes engaged in cognitive activities which are typically associated with psychological essentialism: they appreciated stable kind membership even in the face of trans-temporally changing surfaces. At the same time, the results indicated that dealing with object individuation in more complex settings requires advanced representational and processing abilities. Apes clearly differentiated between the deep level of essential properties and the surface level of apparent properties. All the same, disentangling kind membership from misleading appearances required dealing with a challenging appearance-reality problem (see, e.g.,, Flavell, 1993; Suddendorf, 1997 for a discussion of appearance-reality distinction as a feature of higher-order cognition), since surface properties usually *are* interpreted as a signal to the potential presence of specific kind properties (e.g., bananas usually *are* yellow, even though yellowness is not an essential property of being a banana). Indeed, performance in the different choice task versions varied depending on their cognitive load (e.g., higher cognitive load was associated with lower performance; Cacchione et al., 2016).

In the present study, we pursued two main objectives. The first objective was to test the limits of infants' performance in the more demanding forced choice paradigm (Cacchione et al., 2016). Evidence for infant's relative independence from kind-signaling surface features has so far been provided only by Cacchione et al. (2013), using a low demanding box paradigm. According to our hypothesis, object individuation is a cognitive precursor from which a more mature essentialist perspective emerges later in development. A second relevant element supporting this development might be increasing general processing capacity (see, e.g.,, Needham & Baillargeon, 2000). To assess the robustness of infant's abilities it is important to compare their performance across differently demanding tasks. This evidence is central to assess to what extent sortal object individuation satisfies the same functions as mature psychological essentialism.

A second objective was to directly compare the performance of great apes (Cacchione et al., 2016) with that of human infants. The overarching comparative perspective on pre-verbal representations related to essentialism is needed to truly appreciate the nature of both children's and apes' performance in these tasks. Our previous infant study (Cacchione et al., 2013) is not easily comparable with the ape findings (Cacchione et al., 2016), as these studies involve different procedures (e.g., two-aspect stimuli instead of surface manipulations) and different types of stimuli (e.g., toys instead of food). To directly compare apes' and infants' performance, we adopted the easiest version of the choice task used by Cacchione et al. (2016), to test 14- to 36-month-old human infants. Assessing the age of onset at which infants master the choice task offers additional information regarding the level of cognitive processing required to solve the task (which in turn informs about the type of cognitive processing involved). This is particularly important as the skills studied potentially involve advanced processing capacities (i.e., require disentangling apparent from real kind) and are significantly related to language acquisition, at least in human development (e.g., the use of labels supports sortal object individuation, Gelman & Roberts, 2017; Xu, 2007). A comparative approach thus helps to better understand potential pre-verbal and verbal roots of representations related to essentialism.

Our main research questions were thus the following: Are human infants (like apes) able to identify the preferred object in a set of two objects that were fully transformed in their surface appearance and if so at what age? To address this question, we investigated whether 14-, 18-, 23-, and 36-month-olds would also successfully track object identity in an object choice paradigm involving multidimensional transformations (see Cacchione et al., 2016). Given that adult apes were much challenged by these tasks, we presented infants with the easiest procedure, in which representational and executive demands were reduced and which was solved comparatively well by the apes (i.e., the condition involving only one transformation type and only one food kind, see Cacchione et al., 2016). In the choice paradigm, more domain-general cognitive prerequisites (e.g., general representational abilities and executive functions) are required to solve the task than in the box paradigm used by Cacchione et al. (2013). The comparative focus on this more demanding task provides information about the development of skills related to psychological essentialism. To succeed in this task, identity judgment must be completely independent of surface features, processing capacities must be sufficiently developed to track and compare two objects simultaneously and executive functions must be sufficiently developed to avoid being misled by contradictory surface features. Comparing infants' and apes' performance in this task sheds some light on the relevance of linguistic, representational and executive abilities in this development. In the present experiment, we, therefore, aimed to test at which age human infants are able to solve the task.

Experiment 1

Firstly, we assessed whether infants preferred a round biscuit or a round-shaped wooden block (Preference condition). The preference test did not serve as training but had the purpose of determining which test object (biscuit or block) the children preferred. In the Test condition, we presented infants with the biscuit and the block. In full view of the infants, we manipulated both stimuli, making them look like identical biscuits (see Figure 1). If infants judged the trans-temporal identity of objects according to essentialist principles, they should realize that all objects remain tokens of their kind, even if they have been transformed to superficially look like tokens of another kind (e.g., a wooden block essentially remains a non-eatable wooden item even if it has been superficially transformed to look like a biscuit). Therefore, infants should stick to their preference (i.e., selecting the object preferred in the Preference condition), even after major superficial transformations.

Figure 1. Picture 1 and 2 show the stimuli used: biscuit (left) and wooden block (right) before (picture 1) and after the manipulation (picture 2).

Methods

Participants[1]

We tested 25 14-month-old infants (mean age = 13 months, 29 days, *SD* = 12 days; 16 girls and 9 boys), 24 18-month-olds (mean age = 18 months, 6 days, *SD* = 8 days; 15 girls and 9 boys), 24 23-month-olds (mean age = 23 months, 11 days, *SD* = 21 days; 14 girls and 10 boys), and 24 36-month-olds (mean age = 36 months, *SD* = 47 days; 13 girls and 11 boys). Additional 23 participants had to be excluded, due to fussiness/discomfort (20), due to parental interference (2) and due to experimenter error (1). Participants were contacted by telephone from a database consisting of names of children whose parents had volunteered to take part in studies of child development. Parents filled out a consent form before taking part in our study, and children received a toy for their participation. With regard to SES and ethnic background, the sample was representative of the German population.

[1]This study was conducted in Göttingen, Germany in accordance with the Declaration of Helsinki and the Ethical Principles of the German Psychological Society (DGPs), the Association of German Professional Psychologists (BDP), and the American Psychological Association (APA). It involved no invasive or otherwise ethically problematic techniques and no deception (and there-fore, according to National jurisdiction, did not require a separate vote by a local Institutional Re-view Board; see the regulations on freedom of research in the German Constitution (§ 5 (3)), and the German University Law (§ 22)).

Materials

As stimuli, we used round Bimbono™ baby biscuits (diameter 2.4 cm) and wooden blocks matching in size and shape with the biscuits. Each biscuit was presented in a round biscuit mold (diameter 2.5). The biscuits/blocks were placed in transparent plastic trays (11 × 8 × 3 cm). In the "biscuit transformation" the objects (biscuits/blocks) were placed on plates (d = 16 cm) into biscuit molds and dyed with a light brown liquid plaster and a kitchen brush, in full view of the child. The plaster was made of Alnatura™ semolina mush and was of viscous consistency, matching the appearance of the biscuits in color and texture (see Figure 1 for a picture of the stimuli before and after transformation).

Design and procedure

Before the experiment, the experimenter received parent and child in a reception room where various toys were available. There the experimenter welcomed the parents and the child could play freely. In this warm-up phase (approx. 10 minutes), the experimenter got the opportunity to carefully make contact with the child. Toward the end of this warm-up phase, the experimenter introduced the materials later used in the test to familiarize the child with them. After this warm-up phase, all children underwent first the Preference condition (3 trials), followed by the Test condition (4 trials). Parents were instructed to remain neutral and refrain from directing the child's attention to the plates or providing any feedback. Children sat in front of a table, on the parent's lap, and two plates were placed in front of them, out of their reach (one on the left and one on the right side).

In the first trial of the Preference condition, the experimenter (E) took one tray with biscuits in biscuit molds and one tray with wooden toy blocks (with which children had been familiarized during a short warm-up playing session, before the task started). E showed the stimuli to the child, and called the child's attention by saying "Look what I have here." E then took one stimulus from a tray and placed it on a plate, and then took one stimulus from the other tray and placed it on another plate. After removing both trays, E took the first stimulus and, if it was a biscuit, E cut a small piece, ate it while saying "Mmm, yummy," and handed a small piece to the child to try it. If the first stimulus was a wooden block; instead, E handed the block to the child saying "Wow, look," and let the child play with it for approximately the same amount of time, before gently taking it back. Then, E did the same with the second stimulus, and pushed the two plates toward the child with her hands, without looking at the plates, smiling with a neutral position, and fixing a point at the child's back. The child was then invited to make a choice, by asking "Which one do you want?", repeating the question and slightly shaking the plates in case the child did not make a choice. After the child made a choice, E handed the chosen stimulus to the child and let the child play with it (in case of the wooden block), or cut a piece for the child to eat (in case of the biscuit), and finally cleaned the table by placing everything out of the child's sight. In the following two trials, E simply placed the two stimuli on the plate and let the subject make a choice. We counterbalanced the side of the biscuit and whether it was the first stimulus placed on the plate, ensuring that both the side of the stimuli and their order were never repeated more than once for each child. After the preference test, the children first took a 10-min break, before proceeding to the test condition.

In the Test condition, participants witnessed the manipulation of both stimuli (the biscuit and the wooden block) into two identically "biscuit-looking" items (i.e., both biscuit and block were transformed to look like two perceptually indistinguishable biscuit items from the surface; see Figure 1). E took a tray with biscuits in biscuit molds and a tray with wooden toy blocks, showing them to the child while saying "Look what I have here" in both cases. Then, E let the child encode both stimuli, by cutting a small piece from the biscuit and handing it to the child (Mmm, yummy!"), or allowing the child to handle the block ("Wow, look!"). Then, E took a stimulus from a tray and placed it on one plate, and then repeated the procedure with the other stimulus. After removing both trays, E took a biscuit mold, placed it on the plate, put the block inside, and made an analogous movement with the biscuit, raising it shortly and placing it on the plate again. Subsequently, E took the color and painted the surface of both stimuli with a thick layer, so that both stimuli superficially looked like a biscuit, before placing the paint out of view and pushing both plates toward the child, as in the Preference condition. After the child made a choice, E cut a small piece from the selected stimulus (in case of the biscuit), handed it to the child and cleaned the table by placing everything out of the child's sight. As in the Preference condition, children choosing the block were allowed to handle it (after E quickly cleaned it) for approximately the same amount of time they would have needed to eat the biscuit. The side of the biscuit and whether the biscuit was the first stimulus placed on the plate were counterbalanced within participants, and the order of trials counterbalanced across participants.

Data scoring and analysis

The dependent variable was the number of trials in which infants selected the biscuit. For each participant, we then computed the percentage of trials in which the biscuit had been selected. We used Wilcoxon tests to compare performance between conditions and binomial tests to analyze whether the biscuit was selected above chance in the first trial. All tests were exact and two-tailed, with α level set at 0.05. Twenty percent randomly chosen participants were reassessed by a second coder (naïve to the experimental condition) to calculate inter-rater reliability, which was excellent (Pearson's r =.97, N = 20, p = .001).

Results

The percentage of trials in which biscuits were preferred did not differ across age classes in the Preference condition (Kruskal-Wallis test, χ^2 = 2.972, N = 3, p = .396). In the Test condition, however, age classes significantly differed in the percentage of trials in which biscuits were selected (Kruskal-Wallis test, χ^2 = 30.850, N = 3, p = .000).

All participants selected the biscuit significantly above chance in the Preference condition (Wilcoxon test, 14-month-olds: z = − 4.625, p = .000; 18-month-olds: z = − 4.490, p = .000; 23-month-olds: z = − 3.939, p = .000; 36-month-olds: z = − 3.437, p = .001; see Figure 2). However, only 36-month-olds selected the biscuit more at above-chance levels in the Test condition (Wilcoxon test, 14-month-olds: z = − 1.414, p = .157; 18-month-olds: z = − .924, p = .356; 23-month-olds: z = − 1.734, p = .083; 36-month-olds: z = − 4.231, p = .000). This performance is apparent already in the first trial where only 36-month-olds reliably selected the cookie above chance (Binomial Test, 14-month-olds: observed proportion .60, p = .424; 18-month-olds: observed proportion .63, p = 307; 23-month-olds: observed proportion .67, p = .152; 36-month-olds: observed proportion .92, p = 000). Indeed, all but 36-month-olds selected the biscuit significantly more in the Preference condition than in the Test condition (Wilcoxon test, 14-month-olds: z = − 4.425,

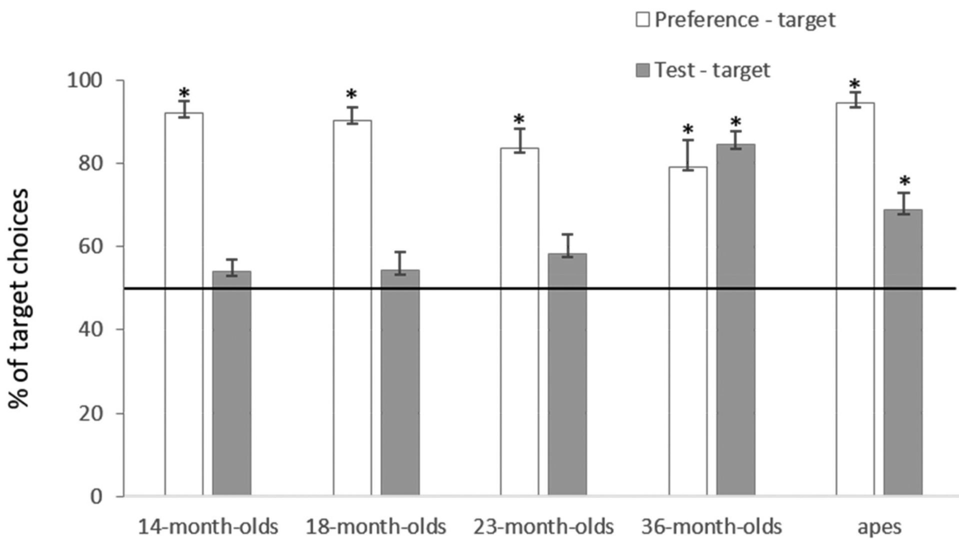

Figure 2. For each age class, mean percentage of trials (+SE) in which children chose the target item in the preference and in the test conditions of experiment 2 (Choice task). Data is compared to performance of great apes reported Cacchione et al. 2016. Target items were biscuits (human children) and banana slices (apes). Asterisk denote above-chance performance.

p = .000; 18-month-olds: $z = -4.048$, p = .000; 23-month-olds: $z = -3.138$, p = .002; 36-month-olds: $z = -.444$, p = .657).

Comparison with ape data *(Cacchione et al., 2016)*

Comparing children's performance with that of apes in the Cacchione et al. 2016 study revealed reliable differences in the Test condition (Kruskal-Wallis test, $\chi^2 = 32.842$, $N = 4$, p = .000), but no differences in the Preference condition (Kruskal-Wallis test, $\chi^2 = 6.433$, $N = 4$, p = .169; means and standard error are depicted in Figure 2). Bonferroni corrected pairwise comparisons revealed that in the Test condition apes performed better than 14-month-olds (Mann–Whitney U test, $N = 53$, $Z = -2.681$, p = .028), but less proficiently than 36-month-olds (Mann–Whitney U test, $N = 52$, $Z = -2.612$, p = .036), while their performance did not differ from 18-month-olds (Mann–Whitney U test, $N = 52$, $Z = -2.228$, p = .104) and 23-month-olds (Mann–Whitney U test, $N = 52$, $Z = -1.672$, p = .38).

Discussion

When testing 14, 18-, 23-, and 36-month-olds with the same object-choice task used with apes, only 36-month-olds could successfully individuate objects, by reliably tracking the biscuit in the face of manipulations changing its superficial features. Therefore, the ability to individuate objects in a task including extensive surface transformations appears to reliably emerge only by 36 months of age. A likely explanation is that extensive domain general cognitive prerequisites are necessary to deal with the task. In the general discussion, we address the cognitive demands associated with the task and elaborate on how they might relate to the ability to engage in essentialist reasoning. Before that, a control is run in Experiment 2.

Experiment 2

Although 36-month-olds could successfully keep track of a biscuit in the face of manipulations affecting its superficial features, Experiment 1 cannot rule out that children were simply using other inadvertent cues provided by the experimenter to individuate objects. In this Experiment, we, therefore, tested 36-month-olds (who were the only successful age class in Experiment 1) with a control condition, in which we mimicked the same movements as in the Test condition of Experiment 1, and only presented the stimuli at the end, after they had been already manipulated out of the children's view. If children relied on cues inadvertently provided by the experimenter to solve the Test condition in Experiment 1, or manipulations were not effective (in that, e.g., children could still rely on some visual cues to recognize the stimuli), children should be able to individuate biscuits also in Experiment 2. If children in Experiment 1, instead, truly appreciated the trans-temporally stable kind of the transformed objects, they should perform at chance levels in this Experiment. The same controls were carried out in case of apes (Cacchione et al., 2016).

Methods

Participants[2]

We tested 24 36-month-olds (mean age = 36 months, 2 days, *SD* = 47 days; 13 girls and 11 boys). Further four participants were excluded due to experimenter error (2) and fussiness/ discomfort (2).

Design and procedure

Participants underwent exactly the same procedure as in Experiment 1, including a Preference condition (3 trials), and a Test condition (4 trials). In this Test condition, however, the experimenter (E) did not manipulate the two stimuli in front of the child. Instead, E mimicked the same movements as in the Test condition in Experiment 2 (e.g., placing the stimuli, "painting" them by mimicking the action with a brush), for approximately the same amount of time, but apart from the two empty plates, the table was always empty. Before pushing the plates toward the child, however, E took two stimuli (i.e., a biscuit and a block, both looking like a biscuit), which had been previously manipulated out of the subject's view, and placed them on the plates.

Data scoring and analysis

As in Experiment 1, we used Wilcoxon tests to compare performance between conditions. Twenty percent randomly chosen participants were reassessed by a second coder (blind to the experimental condition) to calculate inter-rater reliability, which was excellent (Pearson's $r = 1$, $N = 5$, $p = .001$).

[2]This study was conducted in Göttingen, Germany. For ethical regulations see footnote 1, Experiment 1.

Results

Children selected the biscuit significantly above chance in the Preference condition (Wilcoxon test, $z = -3.587$, $p = .000$), but not in the Test condition (Wilcoxon test, $z = -.359$, $p = .720$). Indeed, they selected the biscuit significantly more in the Preference condition than in the Test condition (Wilcoxon test, $z = -3.466$, $p = .001$). A comparison of the 36-month-olds from Experiment 1 with the control group of Experiment 2 revealed that performance reliably differed in the Test condition (Mann-Whitney-Test, $z = -4.912$, $p = .000$), but not in the preference condition (Mann-Whitney-Test, $z = -.532$, $p = .595$).

Discussion

When manipulations were performed out of the children's view, so that no cues were available on the essential properties of the objects, 36-month-olds could not reliably individuate them. Therefore, success in Experiment 1 did not depend on children's ability to use other inadvertently provided cues to track objects, but rather suggests that from 3 years of age children successfully differentiate between deep and superficial properties to assess object kinds in an object-choice task.

General discussion

When testing 14-, 18-, 23-, and 36-month-olds with the same object-choice task used with apes, only 36-month-olds could successfully individuate objects, by reliably tracking the biscuit in the face of manipulations changing its superficial features. Therefore, although a primordial essentialist approach to objects and categories might appear at the age of 14 months (see Cacchione et al., 2013), the ability to individuate objects in a task including more extensive surface transformations appears to reliably emerge only by 36 months of age. Although we kept memory demands relatively low in the present task (see Cacchione et al., 2016), infants up to the age of 23 months still failed to correctly address the true identity of objects after manipulations changing their superficial features. This suggests that infants below 36 months were confused by the misleading kind/property information, and were unable to transcend the level of kinds/properties to focus on spatiotemporal information.

In the present study, we adopted a comparative perspective on the cognitive foundations of essentialism, comparing the essentialist intuitions of human infants with that of apes. Comparing the performance of apes and infants sheds light on the representational and executive abilities related to essentialist reasoning. Also, great apes performed better in the box task (as used in Cacchione et al., 2013) than in the object-choice task (e.g., Cacchione et al., 2016). It is striking that both children and apes experienced so much difficulty with the choice task. The appearance of the objects was transformed, but they remained at exactly the same location during the whole task and could easily have been located on the basis of simple spatiotemporal processing. Long before 36 months of age, children have the ability to locate even occluded objects (e.g., Aguiar & Baillargeon, 1999; Spelke et al., 1995; Wynn, 1992; Xu & Carey, 1996), and the same is true for great apes (see Cacchione & Rakoczy, 2017, for a review). The conflict, under which description the object should be represented after transformation, is objectively unfounded. The difficulties experienced by both apes and younger children likely result from their focusing on featural/kind information and their neglecting spatiotemporal (location) information (probably boosted by the task type, drawing attention away from spatiotemporal information).

Based on the present data, we can only speculate as to why younger children fail at this task whereas apes don't. In the following we briefly discuss potential cognitive correlates associated with the performance in the two task formats, trying to shed light on this question. Although the two task types are superficially similar, they differ in important respects. In the Cacchione et al. (2013) study we used a box task variant with very low processing demands, where only one object is hidden. In the choice task, however, two object trajectories had to be evaluated and compared in the context of extensive manipulations, rendering objects of different kinds superficially equal, so that an appearance/reality conflict arose (i.e., the object looked like a cookie but really was a wooden block, Flavell, 1993; Suddendorf, 1997). Although we confronted children with a simplified version of the choice task (cf. Cacchione et al., 2016), they reached apes' performance level only between 18 and 36 months of age. This suggests that more advanced cognitive abilities were needed to distinguish between simultaneously present real and apparent kinds in the choice task (X *is* a biscuit, but Y is wood and only *appears* as biscuit), than to follow the identity of a single object in the box task (e.g., Cacchione et al., 2013). In terms of processing, the most obvious difference between the two task types is the relative load on working memory (as multiple transformed objects have to be tracked and compared in object-choice tasks). As already observed by Cacchione et al. (2016), working memory was the decisive cognitive factor influencing apes' performance, with only motivational factors being equally important. Indeed, maintaining object representations in the face of distractors typically requires working memory (Stanovich & Toplak, 2012). One possibility is, thus, that the conflict situation in the choice task required the participants to engage in some sort of "decoupling operation," to free themselves from the "deceptive kind" appearance and to give more weight to the original kind representation (a cognitively demanding operation requiring substantial working memory). Cognitive decoupling (i.e., abstracting from primary representations of the directly perceived world, in order to sustain secondary representations) is a capacity usually attributed to higher order cognition (e.g., Type 2 slow reflective thinking: Evans & Stanovich, 2013; Stanovich & Toplak, 2012). Cognitive decoupling fosters the ability to deal with multiple representations/descriptions of one and the same object, and might also be considered of relevance when dealing with appearance-reality problems (in order to decouple the directly perceived "primary" appearance of an object from a secondary represented "reality" of the same object). Such interpretation would be in line with the observation that the choice task was very (even strikingly) challenging, could be solved comparatively late in development and bound a high amount of processing resources. The envisaged developmental course would parallel ontogenetic trajectories in other cognitive domains such as Theory of Mind: more basic capacities of limited representational scope and flexibility (type I) develop early and by far precede the onset of more complex and flexible representational processes (type II) that involve the capacity to deal with multiple and conflicting perspectives (Apperly & Butterfill, 2009).

Considering the cognitive correlates, it seems not surprising that the task overwhelmed the younger children (but surprising that apes succeeded). From an evolutionary perspective, human and nonhuman primates share certain cognitive faculties. Comparative research of the last decades confirms that there are significant similarities in cognitive organization between humans and great apes. It is therefore unlikely that apes solved the task by completely different cognitive mechanisms. It appears possible that the main factor explaining differences between age groups and between species is not language ability but cognitive maturity (and the available executive functions). If this were to be the case, then apes' success would suggest that nonverbal apes share with us some fairly advanced cognitive abilities, and that language is not a necessary prerequisite for these abilities to develop. This in turn could indicate that also in humans language does not constitute these cognitive abilities alone, but builds on a preexisting conceptual structure and qualitatively enriches and enlarges it. However, it would be premature to draw any firm conclusions based on the present findings alone. More research from a comparative perspective is needed to trace and compare the developmental trajectories of these abilities and to better understand the cognitive similarities and differences between these two species.

The present study investigated the roots of psychological essentialism comparing the performance of human infants and apes in the context of the more demanding choice paradigm. Previous research using the box paradigm (Cacchione et al., 2013) revealed infants' independence from kind-signaling surface properties in object individuation (e.g., shape), suggesting that kind-based individuation may lay the cognitive foundation to an essentialist stance toward the world. Findings of the present study suggest, however, that kind-based individuation *and* increasing representational and executive capacities are linked in important ways in the development of a full-fledged essentialist perspective (a finding observed also in other contexts, see, e.g., Wilcox & Baillargeon, 1998; Xu & Baker, 2005). Not before the age of 36 months did infants successfully track fully transformed items in the face of increased processing demands in events modeled after the transformation scenarios used with older children (e.g., Keil, 1989). Nevertheless, we think sortal object individuation as measured by the box task does constitute a primordial form of essentialism. Essentialism offers a tool to appreciate stable object identities, by allowing the maintenance of a certain description under which an object is currently represented in the face of perceived surface feature changes. Sortal object individuation fulfills exactly this function by providing a criterion to associate a certain range of "legitimate" appearances with one underlying deep nature (distinguishing between deep and surface properties, as well as between legitimate and illegitimate appearances). To our view, this ability came to bear both tasks types as children were required to differentiate between assumed (essential) and perceived surface features properties. However, only in the choice task did they have to do so under conditions of cognitive load.

A possible caveat of the present studies is that the color manipulation might have had a different impact on infants' identity judgment in the context of food items (than would have been the case with toys, for example, see, e.g., Shutts, Condry, Santos, & Spelke, 2009). This may be one reason for the rather weak performance as compared to the Cacchione et al. 2013 study, involving toys. Moreover, the younger infants might have been especially challenged by these manipulation tasks, as they might generally be less experienced with the surface manipulation of objects than older children. It is, therefore, possible that the younger infants were confused by the painting of biscuits (not being familiar with food painting) or, on the contrary, were particularly interested in the painting of building blocks (and therefore preferred to explore the painted blocks), etc. Future studies are certainly needed to better understand the relationship between kind and featural information when individuating specific kinds of objects and to learn more about the nature of cognitive processing in these tasks.

Together with the earlier findings on great apes (Cacchione et al., 2016), findings from the choice task show that later forms of essentialist reasoning (as, e.g., measured in verbal transformation tasks) require advanced representational and executive capacities. Before the age of 36 months, this clearly exceeds children's cognitive resources. For this reason, apes' success (Cacchione et al., 2016) appears very remarkable indeed, providing evidence for true sortal object individuation, and speaking against the possibility that the task was solved by complex feature placing. Overall, these results indicate a relatively sophisticated conceptual approach to the world, in the absence of language. In particular, they imply that precursors and/or basic forms of essentialist thought develop early in humans, and exist independently of sophisticated linguistic and cultural influences also in other species in the primate lineage, and possibly beyond.

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