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Sortal concepts, object individuation, and language

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Cognitive science is an interdisciplinary enterprise. This review highlights how the philosophical notion of a 'sortal' – a concept that provides principles of individuation and principles of identity – has been introduced into cognitive developmental psychology. Although the notion 'sortal' originated in metaphysics, importing it into the cognitive sciences has bridged a gap between philosophical and psychological discussions of concepts and has generated a fruitful and productive research enterprise. As I review here, the sortal concept has inspired several lines of empirical work in the past decade, including the study of object individuation; object identification; the relationship between language and acquisition of kind concepts; the representational capacities of non-human primates; object-based attention and cognitive architecture; and the relationship between kind concepts and individual concepts.

From philosophy to psychology

The study of concepts has been central to cognitive science. Both philosophers and psychologists have proposed theories of concepts and concept acquisition; however, the two groups of scholars often find themselves talking at cross-purposes. For philosophers, concepts are 'constituents of thought'. The study of concepts focuses on how concepts are individuated and acquired; how to distinguish concepts from beliefs; how concepts might support individuation, categorization and inference; and how – as 'units of thought' – concepts underlie word meanings, enabling conceptual combinations that satisfy conditions such as compositionality in order to interface with syntax and semantics [1–3]. For psychologists, concepts are "mental representations that support categorization behavior" [4]. Discussions between philosophers and psychologists about concepts have sometimes been frustrating and counterproductive because the two fields of inquiry focus on different issues [5,6].

The study of sortal concepts and object individuation in recent years has attempted to bridge the two communities. Since Aristotle, there has been a rich tradition in philosophy of the study of individuals, kinds and sortals; psychologists have now taken up this line of inquiry, developing it into a productive program of research. This review summarizes the research on sortals and object individuation from the past decade, and it showcases how the cross-fertilization between disciplines has engendered new questions, new paradigms and new answers.

What is a sortal?

A sortal is a concept that provides principles of individuation and principles of identity [7–9]. To answer the question 'how many?', we need to specify how many of what. If we were interested in counting the number of items in a room, we would receive different answers by asking 'how many TABLES?', 'how many CHAIRS?' or 'how many LEGS?'. Similarly, to answer the question 'is it the same?', we need to specify 'the same what'. A person might not be the 'the same BABY' as she was 17 years ago, but she might still be 'the same PERSON'. Our identity criteria are sortal-specific, in the sense that the same property difference might or might not indicate a change of identity, depending on the kind of object in question (e.g. a change in size and color indicates a change in identity for a chair but not necessarily for a plant). Sortal concepts enable us to enumerate and to track identity over time, and they are lexicalized as count nouns in languages that make the count–mass distinction.

All concepts provide principles of application (which specify what falls under the concept), but not all concepts provide principles of individuation and identity. Consider the concept red. We cannot count the 'red' in a room, unless we specify a sortal: 'red shirts', 'red lights' or 'red-heads.' We also cannot count the 'good', but we can count the number of 'good people', 'good thieves' or 'good knives'. Adjectives such as 'red' and 'good', thus, do not support individuation. Similarly, we cannot ask whether something is 'the same red' or 'the same good', unless we specify 'the same red shirt' or 'the same good thief'. 'Red' and 'good' do not support identification. Generally speaking, the interpretation of predicates (whether they are adjectives, verbs or other grammatical classes) depends on the noun [10].

The general methodological stance adopted here is that the study of concepts can be informed by the structure of natural language, whereby the largely universal grammatical classes serve as a heuristic for subdividing our concepts: count nouns tend to map onto kinds of individuals, mass nouns tend to map onto kinds of non-individuated portions, adjectives tend to map onto attributes or properties, and so on. Words might or might not come before concepts, but the division of labor among the grammatical classes in natural language can provide some useful hints for the study of cognition. If different types of concept fulfill different logical functions and have different structures,

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then the study of concepts and word meanings should respect these boundaries [8,11,12].

Object individuation and sortal concepts

Object individuation is the process by which we establish the number of distinct objects in an event. When an object is seen at time 1 and an object is seen at time 2, the question arises as to whether the same object is seen on two different occasions or whether two distinct objects are present. For adults, at least three sources of information are used in individuating objects: spatiotemporal information, property (featural) information, and sortal information [7,13].

Spatiotemporal information includes generalizations such as objects travel on spatiotemporally continuous paths and two objects cannot occupy the same space at the same time. For example, the blue teacup that is in front of you now is not likely to be the same object that was seen in a faraway place such as Australia 10 minutes ago, because no object can traverse a spatiotemporally connected path between these two locations in such a short amount of time. These generalizations are true for all objects, regardless of their kind.

Property information includes generalizations such as objects do not usually change size or color. For example, the blue teacup that you see now is not likely to be the same object as the yellow teacup that you saw 10 minutes ago.

Sortal information includes generalizations such as objects do not change kind membership; if an object seen at time 1 falls under one sortal concept and an object seen at time 2 falls under another sortal concept, then they must be two objects. For example, the blue teacup that you see now cannot be the same object as the blue pencil you saw 10 minutes ago. Furthermore, property information is sortal-specific such that property differences are weighted differently depending on the kind of object under consideration. For example, if a small green plant is replaced by a large leafy one in a month, it might well be the same individual that has grown over time. By contrast, if a small green cup is replaced by a large green one, it is very unlikely that they are one and the same cup. The criteria by which children individuate objects can serve as a means for investigating at what age children can represent sortal concepts.

The developmental origin of sortal concepts

Much evidence obtained with the violation-of-expectancy looking-time methodology suggests that infants as young as 4 months represent the sortal OBJECT and they use spatiotemporal information to determine how many objects are in an event [14]. If objects appear to have traveled on spatiotemporally discontinuous paths (Figure 1), infants posit two distinct objects in the event. That is, they look longer at the unexpected outcome of one object than at the expected outcome of two objects. Many laboratories have replicated and extended these findings [15,16]. Younger infants, however, have a limited understanding about occlusion events, and their use of spatiotemporal discontinuity is more fragile [17,18] (Box 1).

Representations of other sortal concepts develop towards the end of the first year. By 10 months, infants represent the sortal PERSON [19]. When a doll's head emerged from behind an occluder and returned behind it, and then an inanimate object emerged from behind the same occluder, infants were found to establish a mental model of two objects. They looked longer if the occluder was removed to reveal just one of the two objects. Furthermore, in the same is-it-one-or-two task, 10-month-old infants failed to expect two objects when given a male doll's head and a female doll's head, or when given two different toy dog-heads in the same event. It seems that the infants' success is based on the sortal distinction between a person (or human head) and an inanimate object, and not on the property distinction between two people. These findings suggest that, in addition to the sortal concept object, infants represent PERSON as a sortal by 10 months of age.

It is not until 12 months of age that infants represent sortal concepts that correspond to what psychologists call 'basic-level categories' such as DUCK and BALL [20]. In the is-it-one-or-two task, when a duck emerged from behind an occluder and returned behind it, and then a ball emerged from the same occluder and returned behind it, 12-month-old but not 10-month-old infants expected to see two objects when the occluder was removed (Figure 2). Importantly, control experiments showed that the infants had encoded the perceptual differences between the objects, but they failed to use these differences to compute the number of objects in the event. Other laboratories have replicated and extended these findings by using looking-time and manual search measures [21–26].

Parallel to the results with 10-month-old infants in the doll's head experiments, 12-month-old infants failed to expect two distinct objects behind the occluder if the objects differed in only color (e.g. a red ball versus a green ball), only size, or a combination of size, color and surface pattern. Infants expected two distinct objects, however, if the objects differed in shape that was indicative of a sortal distinction (e.g. a cup versus a bottle of the same size, color and surface pattern) but not if they differed in shape that was not indicative of a sortal distinction (e.g. a regular cup with one handle versus a sipping cup with two handles and a top lid) [27]. It seems to be the sortal distinctions that underlie success at 12 months, not just property differences.

Box 1. Object-based attention and cognitive architecture

The notion of an object has played a central part in the study of attention. Researchers have discovered several parallels between the study of the object concept in infancy and the study of object-based attention: the primacy of spatiotemporal information, the secondary role of property information, the limit of tracking three or four objects at a time, and the fact that object-tracking respects constraints such as cohesion. These parallels have inspired psychologists to put forth the hypothesis that the two fields are investigating the same natural kind [53–58]. The proposal is that infants start life with a mid-level object-based attention system, and the principles that guide their reasoning about objects are embodied within the attention mechanism itself. In this view, the early concept of an object sits at the interface between perception and concept, and it is only when basic-level sortal concepts, such as, person, dog and cup, are acquired that it can be warranted to say that infants have true concepts.

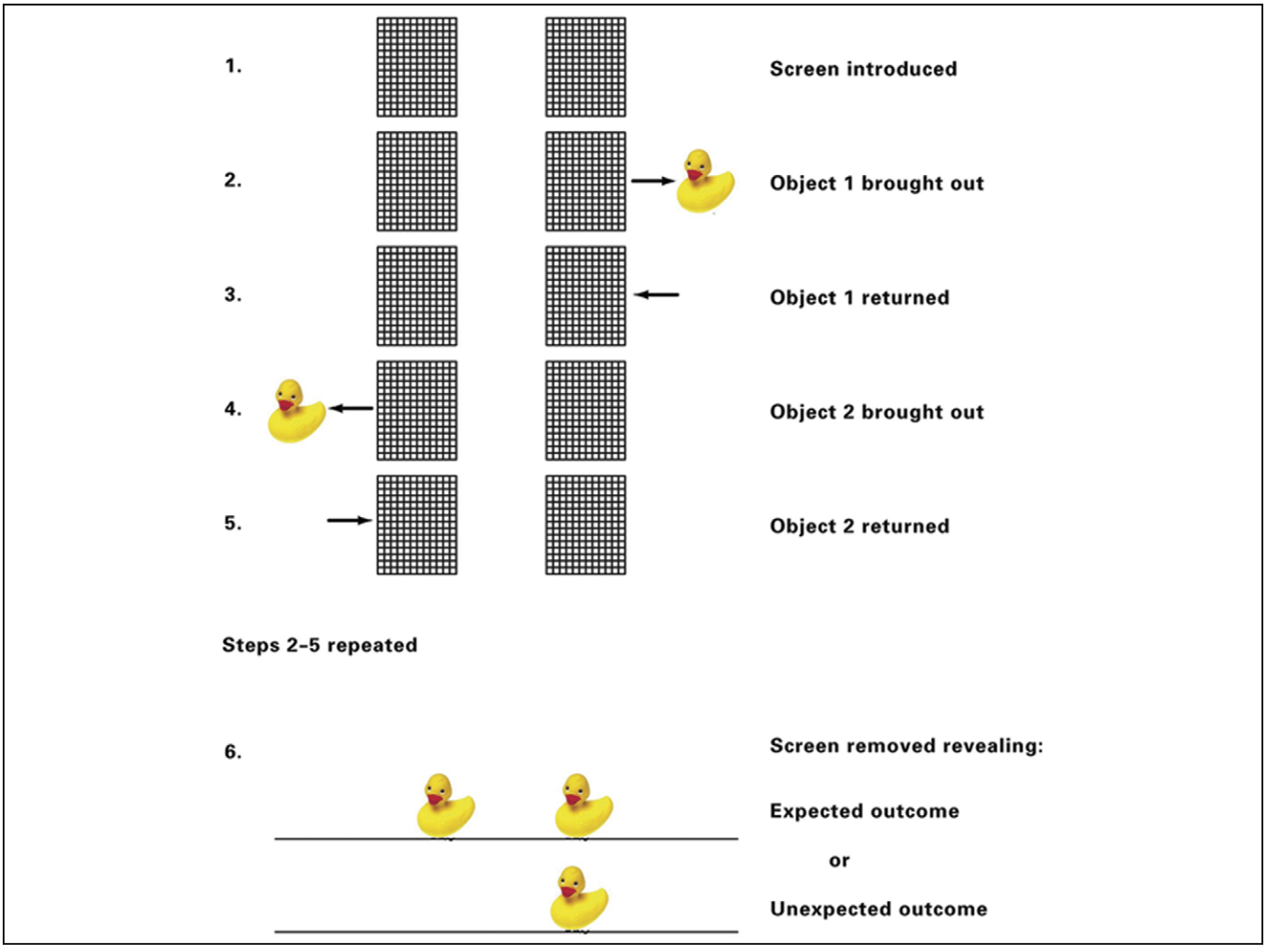

Figure 1. Schematic representation of the discontinuous event. Infants watch the event unfold on a stage. The occluders are placed on the stage. An object emerges from behind one occluder and returns behind it; subsequently, a physically identical object emerges from behind the second occluder and returns behind it. No object appears in the space between the two occluders. Because objects travel on spatiotemporally continuous paths, the spatiotemporal discontinuity provides evidence that there are two identical objects in the event, one behind each occluder. When the occluders are removed in test trials, infants' looking times are recorded for the expected outcome of two objects and the unexpected outcome of one object [14].

The use of property information in object individuation

Although the initial evidence suggests that infants younger than 10 months cannot use property information for object individuation [20], subsequent empirical work indicates otherwise. When the experimental procedure is simplified, 10-month-old infants succeed in using property information to establish two objects in an event using either looking time or manual search as the dependent measure [23,28]. There is also a developmental progression of the perceptual dimensions that infants use in object individuation: by 4.5 months infants use shape and size as the basis for object individuation; but it is not until 7.5 months that infants use pattern, and 11.5 months that they use color and luminance information to do so [29,30]. Interestingly, when younger infants are given information that color is predictive of object function, 9.5-month-olds succeed in using color for object individuation [31]. More recently, 4.5-month-old infants have also been shown to be able to use some object sounds – those that are linked to the physical properties of objects – to individuate objects in an occlusion event [32].

Why is it that in some tasks infants succeed in using property information as the basis for object individuation, whereas in other tasks they fail? One proposal suggests that the complex tasks require the infants to map different types of event (e.g. occlusion and no-occlusion events), and this mapping is a source of difficulty for them [23,33,34]. If infants are presented with events that require them only to keep track of objects over occlusion, they can use property information to determine how many objects are behind the occluder. By contrast, if infants are presented with events that require them to keep track of objects over occlusion first, and then to map this representation onto an outcome when the occluder is removed, the complexity of the mapping might prevent the infants from using property information for object individuation. Another possibility is that some tasks are methodologically more complex (e.g. if there are more reversals of the trajectories of objects, higher memory demand, or more complex objects) [35]. A third suggestion is that the differences in infants' performance reflect the relative strengths of the different sources of information that can be used for object individuation [28].

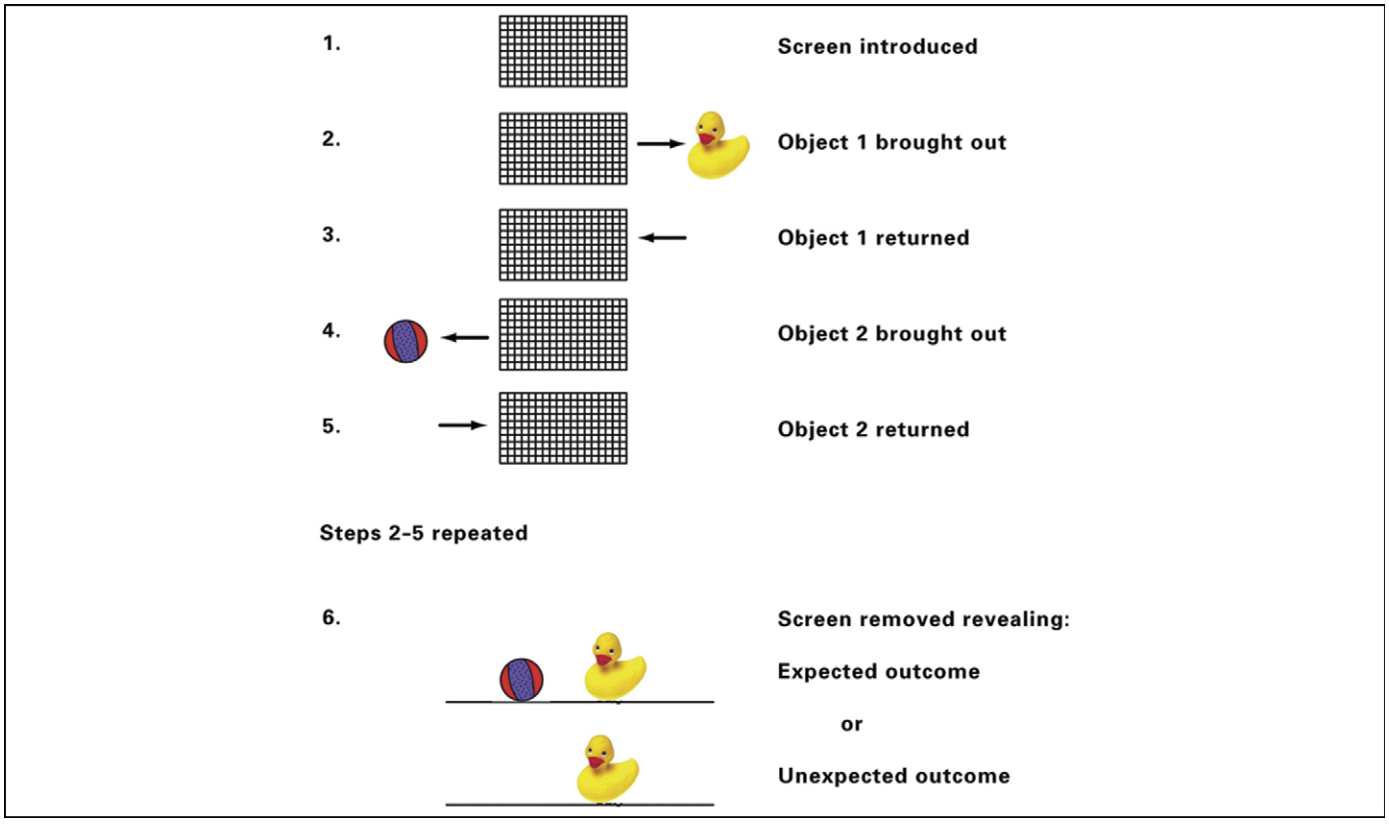

Figure 2. Schematic representation of the property or kind condition. The occluder is placed on the stage as the infants watch. A toy duck emerges from behind the occluder and returns behind it, followed by a ball emerging from the other side of the occluder and returning behind it. Because the objects fall under two sortal concepts, duck and ball, it follows that two distinct objects are behind the occluder. When the occluder is removed in test trials, infants' looking times are recorded for the expected outcome of two objects and the unexpected outcome of one object [20].

In the simplified tasks, property information might be the only source of evidence available, and early sensitivity in using property information for object individuation can be detected in these models. In the more complex tasks, by contrast, strong spatiotemporal evidence overrides property information – much like the perceptual phenomenon of apparent motion or the tunnel effect – and it leads younger infants to posit one object with changing properties in their mental model. By 12 months of age, the emergence of sortal concepts such as duck or ball serves to overcome strong spatiotemporal evidence of one object, resulting in the more adult-like representation of two objects.

The role of language in acquiring sortal concepts

Over the course of the first year, infants gradually develop representations of sortal concepts: first OBJECT, then PERSON (and perhaps other ontological kinds such as ANIMAL), and then basic-level sortals such as DUCK, BALL and CUP.

How do infants acquire basic-level sortal concepts? Studies with 9-month-old infants suggest that learning count nouns that map onto kinds of objects can play a causal role in this process [36]. Nine-month-old infants were presented with the is-it-one-or-two task. When each object emerged from behind the screen, the experimenter labeled it: 'Look, a duck!' or 'Look, a ball!' With just a few repetitions of these labels, 9-month-old infants behaved like 12-month-olds in the test trials: they looked longer at the unexpected outcome of one object than the expected outcome of two objects. Infants also succeeded when two unfamiliar objects were presented and nonsense words were used. By contrast, they failed when both objects were labeled 'a toy,' or when two distinct tones, sounds or emotional expressions were provided. One hypothesis is that infants expect words (count nouns) to refer to sortals, and the use of two distinct labels signaled to the infant that two kinds of objects were presented in the event; therefore, two objects must be behind the screen. Other laboratories have replicated and extended these results [26].

Further evidence suggests that the words did not provide the infants simply with a mnemonic during these experiments. In two studies, parents of 10- and 11-month-old infants were asked to report on their infants' word comprehension for a set of highly familiar objects. When these objects were used in the is-it-one-or-two task without labeling, the results showed that infants who knew both words for the objects used in the task succeeded, but those who did not know the words failed [20,26]. Another study tested whether labeling alone could guide the process of establishing representations of distinct objects. Using a manual search method, 12-month-old infants were shown to be able to apply the presence of labels to determine how many objects were in a box whose content was invisible to them [37]: when infants heard the content of the box labeled with two different words, they expected to find two objects inside; when they heard just one word

repeated, they expected to find only one object inside the box.

These experiments show that infants expect two objects upon hearing two different labels. Do infants, like adults, expect two distinct labels to refer to two kinds of objects and not just two individual objects? In one study, 9-month-old infants were first shown two possible outcomes: either two identical objects or two different objects. The infants were then given linguistic information about the content of the box by using either two labels or one label repeated. Looking-time results showed that infants expected to see the different object outcome when they heard two labels and the identical object outcome when they heard just one label. Additional experiments showed that infants expect two distinct words to map onto two different-shaped objects but not two different-colored objects [38]. Because shape is a perceptual dimension that is often correlated with kind membership and color is not [39], it seems that even 9-month-old infants expect distinct count nouns to map onto distinct kinds of objects, not just individual objects (Box 2).

Other aspects of conceptual development such as categorization and inductive inference are also influenced by linguistic information. Categorization in 9-month-old infants is facilitated by the presence of a consistent count noun label [40,41], and the provision of a common label enables 13-month-old infants to generalize a non-obvious sound property from one object to another [42]. These studies converge with the results of the object individuation studies: infants expect count nouns to map onto kinds of objects at the beginning of word learning, and this expectation leads them to use labeling as a source of evidence in identifying kinds in their environment. The labeling event 'Look, a rabbit!' informs the infant that she should set up a mental symbol that represents a sortal concept; the sortal concept RABBIT maps onto the kind rabbit in the world. If an object seen at a different time is labeled with a different count noun, 'Look, a dog!', a mental symbol is then created to represent the sortal concept DOG. These sortal concepts provide the basic criteria for individuation and identity: an object that falls under the sortal RABBIT cannot be the same object as one that falls under the sortal DOG. In this sense, the acquisition of basic-level sortal concepts depends on acquiring basic-level count nouns.

Box 2. Sortal concepts and individual concepts

What is the relationship between sortal concepts and individual concepts? The philosophical literature on sortals makes the strong claim that representations of individuals depend on representations of sortals. That is, it is not possible to pick out an individual (i.e. a bare particular) without specifying some principle of individuation, which is supplied by sortals [7–9]. Psychological studies of individual concepts, however, have disputed this claim. Some have argued that representations of individuals are autonomous from sortals, as judged by a person's apparent willingness to track individual identity through changes in sortals, leading to proposals of other mechanisms such as 'causal continuity' as a basis for tracing the identity of individual objects [59,60]. Others have suggested that representations of sortals emerge earlier in development than does understanding of the causal knowledge needed for tracking individuals, supporting the primacy of sortal concepts [61,62].

Object identification in infants

An important conceptual distinction has also been drawn between object individuation and object identification within the object-indexing framework [43]. Object individuation refers to the process of establishing object representations, whereas object identification refers to the process of binding property information to the existing object representations such that objects can be re-identified at another time. In other words, object individuation answers the question 'how many', whereas object identification answers the question 'which one'.

In object identification studies, the number of objects is usually kept constant. Instead of testing the infants' sensitivity to whether the event contains one or two objects, these experiments ask the infants to bind object features to locations. At 1 month, infants are sensitive to conjunctions of shape and color with face-like stimuli [44]; at 4 months, infants are sensitive to a change in location but not to changes in object features or to the combination of location and features when presented with pictures of toys (interestingly the pattern is reversed when the stimuli are images of faces) [45]. By 6.5 months, infants can bind shape to one but not two objects in an occlusion event; by 9 months, infants can bind shape but not color to two objects; at 12 months, infants continue to find it difficult to bind color to two objects [46–48].

Non-human primates and representation of sortal concepts

If the acquisition of basic-level sortal concepts in humans depends on learning basic-level count nouns, what happens in non-human primates? Converging evidence suggests that chimpanzees, rhesus monkeys and cotton-top tamarins can use property information for object individuation in an is-it-one-or-two task using looking time or manual search as the dependent measure [49–52]. It remains to be seen whether

Box 3. Questions for future research

- Do 12-month-old infants represent fully fledged sortal concepts? Presumably not. Infants have yet to acquire many specific beliefs about the various kinds of objects in their environment and, as they mature, their identity criteria for tracking objects as kinds of things become more elaborate and more accurate [63–65].
- What exactly is the role of language? And how long lasting are the effects of labeling? Labeling can enable the infants to establish initial representations of sortals, but does it also entail shared non-obvious and deeper properties, or even essences [66]?
- Are basic-level categories and basic-level sortal concepts the same thing? The discussion of sortal concepts and object individuation introduces a new set of terminology, which needs to be integrated with psychological discussions of concepts and categorization [67].
- What is the relationship between sortal concepts and psychological essentialism? Some have suggested that the internal structure of sortal concepts embodies the basic tenets of psychological essentialism [67]. This proposal needs further explication in terms of how causal structure is related to representations of sortal concepts, kinds and essences.
- What is the neural basis for representations of individual and sortal concepts? How does the brain keep track of individual objects through time and space, and how are representations of individual objects integrated with representations of sortals and kinds?

non-human primates also represent sortal concepts in addition to property differences; in other words, can they use the distinction between cantaloupe and carrot, and not just the property differences between green and round versus orange and skinny, in object individuation tasks?

Concluding remarks

To metaphysicians, a sortal "gathers up a class of things that survive certain sorts of change, come into being in a certain specific way, tend to be qualified in certain specific ways, and tend to cease to be in certain specific ways" [9]. To psychologists, importing the notion of a sortal, psychologizing it, and developing empirical research to address the question of its developmental origin have enabled us to ask certain theoretical and empirical questions that had not been asked before. A decade later, many questions have been asked, some have been answered, and others remain open (Box 3). The research on sortals has presented a strong case where an interdisciplinary approach to the study of concepts has been proven to be fruitful and productive.

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