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Relative contributions of kind- and domain-level concepts to expectations concerning unfamiliar exemplars Developmental change and domain differences

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Abstract

Two inferential routes allow children to produce expectations about new instances of ontological categories like "animal" and "artefact." One is to generalise information from a "look-up table" of familiar kind-concepts. The other one is to use independent expectations at the level of ontological domains. Our experiment pits these two sources of information against each other, using a sentence-judgement task associating properties with images of familiar and unfamiliar artefacts and animals. "Strange" properties are compatible with the ontological concept, but not encountered in any familiar kind. A look-up strategy would lead children to reject them and an independent expectation strategy to accept them. In both domains, we find a difference in reaction to strange properties associated with familiar vs. unfamiliar items, which shows that even young children do use independent domain-level information. We also found a U-shaped curve in propensity to use such abstract information. In addition, animal categories are the object of much more definite domain-level expectations, which supports the notion that the animal domain is more causally integrated than the artefact domain.

Keywords: Concepts; Domain-specificity; Category-specificity; Animal; Artefact

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1. Introduction

Children between 3 and 10 develop a large number of *kind-concepts* for animals and artefacts. This is clear in the lexical explosion that occurs at the beginning of that developmental period (Clark, 1993) and in children's performance in categorisation tasks (Gopnik & Meltzoff, 1987). Most of these concepts correspond roughly to the "basic" level of categorisation where between-classes similarity is reduced and within-classes similarity is maximal (Dickinson, 1988; Hall, 1993; Waxman, 1991). These are, for instance, concepts of "giraffe," "cow," "car," or "telephone." Count-nouns are generally associated with such kind-concepts rather than with superordinates, subordinates, part-, or property-concepts (Waxman & Markow, 1995).

Children also develop, from infancy, more abstract concepts for superordinates of the basic concepts, e.g. "animal," "artefact," or "person" (Mandler & Bauer, 1989). These *domain-concepts* do not generally correspond to early-acquired lexical entries. Nor are they connected to maximally integrated features. However, they constrain inferences, for instance, about both familiar and unfamiliar animal and artefact categories.

These two levels of conceptual information (henceforth "kind-concepts" at the basic or near-basic level and "domain-concepts" at the ontological level) are also found in adult semantic memory. They store different kinds of information. Various behavioural measures demonstrate the difference between conceptual associations retrieved at domain level and those available at the "entry level," i.e. kind-concept level (Chumbley, 1986; Jolicoeur, Gluck, & Kosslyn, 1984; Kosslyn, Alpert, & Thompson, 1995). We now have some evidence concerning both the sources of domain-level inferences (the database that is activated) and the processes engaged (inductive generalisation, instance-based generalisation, analogy, theory-like principles). The aim of the present article is to provide a better description of the developmental course of inferences from familiar to unfamiliar stimuli in the domains of animal and artefact concepts, highlighting domain and age differences in sources and processes of inference.

It is still not entirely clear how domain-concepts are constructed by children and how they connect with kind-concepts at or near the basic level. To some extent, an accumulation of features represented in kind-concepts certainly supports inductive generalisations in domain-concepts (see e.g. Eimas, 1994 for the "animal" concept). This is the most plausible route whereby children learn, for instance, that most tools are in fact made of hard materials or that most mammals' bodies are warm. However, at a deeper level, there is considerable evidence that information flows in the other direction as well. First, domain-concepts produce *expectations* about instances of kind-concepts. Preschoolers, for instance, expect animals to move around of their own accord, but not artefacts, even if the latter look like animals and even though the child cannot explain why she has these divergent intuitions (Massey & Gelman, 1988). Second, there is evidence that in many cases these expectations are *systematic*, that is, interconnected rather than merely juxtaposed. Preschoolers expect animals to move around because they are "driven" by internal states and to be in these states because of external circumstances. Third, expectations from domain-concepts appear in many cases to be *theoretical*, in the sense that they go far beyond obvious features of known instances (Gopnik & Meltzoff, 1987). For instance, children expect the "insides" of animals to be more crucial in producing behaviour than their "outsides," although the latter are of course critical in the identification of instances (Gelman & Wellman, 1991).

These different phenomena suggest that domain-concepts have direct effects on the construction of kind-concepts. Kind-concepts may be initially triggered by nonprincipled detection of similar features in different instances, notably by shape (Landau, Smith, & Jones, 1988; Quinn & Eimas, 1997). However, efficient categorisation would require constraints on similarity (Medin, Goldstone, & Gentner, 1993; Rips, 1989) and such constraints are indeed found in children (Keil, 1994). Identification of an object as belonging to a particular domain (e.g. animal vs. artefact) determines which aspects of the exemplar then count towards membership in a kind-concept (Soja, Carey, & Spelke, 1992). The format of domain-level information used in such inferences is variously described as a set of "skeletal principles" (Gelman, 1990), as "modes of construal" that emphasise distinct forms of causation (Keil, 1986, 1994), or as "foundational theories" that specify an ontology and specific causal principles for a whole domain (Wellmann & Gelman, 1992).

These different theoretical accounts converge in assuming that information from domain-concepts does constrain inferences from familiar to unfamiliar kinds. This can be demonstrated in three different ways. First, attributing some property to a new kind "attracts" application of other properties, thereby showing that properties hold together within a domain; anything that is described as "sleepy" may be "hungry" but not "made of metal" (Keil, 1979, 1986). Second, one can suggest that an instance of a known kind K (e.g. "cat") has a property P that is new to the child (has a spleen) and measure to what extend the child extends P to other instances of K (other cats have spleens), to instances of other kinds in the same domain (e.g. dogs have spleens) and to instances in other domains (e.g. do telephones have spleens?) (Carey, 1985, 1988). Third, one can present unfamiliar items that belong to no known kind-concept but are clearly identified as belonging to a domain (e.g. an aardvark) and measure what properties of known kinds (e.g. eats, breathes, moves around as cats and dogs do) are spontaneously extended to that new kind (Carey, 1988; Gelman, 1988; Gelman & Markman, 1986; Gelman, Gottfried, & Coley, 1994).

These techniques reveal a great deal about the contents and organisation of information at the level of domain-concepts. However, there remain three difficult issues as regards that information: (1) What are the relative contributions of independent domain-level information vs. generalisation from kind-concepts in children's inferences? (2) What are the developmental changes in the use of such information? (3) Are there domain differences in that use?

Let us first consider the question of sources of information. A child's expectation that a cow cannot be manufactured by assembling parts of other cows might stem from kind-knowledge (cows grow out of calves born of cows) or from domain-knowledge (animals are things that are born and grow, they are not assembled). That children have the same intuition for unfamiliar animals (i.e. they judge that the new, unfamiliar animal was not made by assembling parts) still leaves open two possibilities. The first one, which we call here a "look-up table account," is that information that supports intuitive judgements about new kinds is extracted by comparison with known ones. In this case (still taking the animal domain as an example), to determine whether a new animal could be assembled from detached parts, children would search through concepts like "cow," "cat," "dog," etc. Failing to find this feature in any of their kind-concepts, they would infer that the feature is unlikely in new animals. The second possibility, which we call the "independent information" account, is that ontological concepts include specific information independent of what can be induced from basic kind-concepts. For instance, the "animal" category might include abstract requirements on the way animals develop, which would exclude that they could be assembled from parts. We are not suggesting that these processes are mutually exclusive, but we need to evaluate their relative contributions to actual inferences.

To measure this, we constructed a special set of what we call "strange" properties. These are compatible with the ontological category, yet, they are not found in any basic kind known to the child (see complete table in Appendix A). An illustration is "a [new] animal that eats paper." Many adults do not know that some insects actually eat paper, but they generally judge it plausible that some animals, which they do not know, may feed on paper. Such *strange* properties are of particular interest when applied to *unfamiliar* items because they create a potential conflict between kind- and domain-level information. If the "look-up table" account is correct, children should consider such situations implausible, since none of their basic kind-concepts includes the feature "eats paper." (We assume that the child does not know about termites). If the "independent information" account is correct, the child should accept the scenario. Given that different animals have a different diet, there should be no principled restriction on what a new animal could eat. So "strange" properties (henceforth without quotes) are such that their association with an unfamiliar item should result in opposite judgements, depending on whether children use basic kinds for inductive generalisations or else use independent domain-level information.

Another question that requires more specific evidence is that of developmental changes in domain-based inferences. If "look-up" processes are dominant, one should expect children to become gradually more tolerant of strange properties (as defined here) applied to unfamiliar animals and artefacts. This would be because the accumulation of kind-concepts would make the limits to variance within domains more and more salient. By contrast, if "independent information" dominates inferences, we would predict that acceptance of such scenarios as plausible is less likely to change during development. If anything, accumulation of kind-concepts and knowledge of these kinds during middle childhood should make children less likely to accept strange properties by making “look-up table” access more easily available and inferentially richer.

Finally, the relative contributions of both sources of information may display domain differences. Note that many of the findings mentioned above (about “skeletal principles” or “theories”) are about the domain of animate beings, in particular about their “essential” and psychological features. Preschoolers seem to use a rich inferential base for their inferences about the features and behaviour of animate beings.

It is more difficult to provide evidence for corresponding theory-like principles in the domain of artefacts, even if we restrict the domain to familiar tools, machines, and utensils, although young children have many basic-level concepts of such artefacts (Gelman, 1988). For instance, young children do not seem to reject category membership for familiar artefacts with modified functional details (e.g. scissors with no central screw) (Gentner & Ratterman, 1991). On the other hand, even preschoolers can associate familiar objects with their usual function and produce quasiteleological inferences about the functional features of objects (e.g. that scissors have sharp blades so they cut well, Keil, 1986). They can use functionality to decide whether unfamiliar-looking exemplars are members of a known artefact category (Richards, Goldfarb, Richards, & Hassen, 1989). They can also pay attention to functional affordances if they have direct experience of object use (Kemler Nelson, 1995).

Our difficulties with the artefact domain-concept in children may not be surprising, in view of equally ambiguous findings with adults. The latter certainly use possible function(Ahn, 1998), as well as intended function (Bloom, 1996, 1998) among the central features of artefact *kinds*, but they tend to extend artefact *labels* to atypical exemplars on the basis of shape as much as functionality (Malt, 1993). A possible interpretation of these findings would be that kind-level information does not feed into (or become constrained by) domain-level information in the same way for the animal and artefact domains. The point of our experiment was precisely to evaluate whether such connections (between kind- and domain-level information) are established in children, and whether they differ between domains.

2. Experiment

We tried to evaluate the extent to which children made use of ontological-level knowledge in judging whether new situations were plausible or not. We used strange properties (as defined above) associated with familiar and unfamiliar items in two different categories, animals, and artefacts. Both categories are rather narrowly construed here. All animals were mammals and birds, all artefacts were tools or tool-like contraptions. To evaluate possible biases in the child’s general tendency to accept or reject scenarios with “strange” properties, depending on either item familiarity or category, we also used two other kinds of properties. "OK" properties are those that adults judge true of all members of an ontological category, familiar or not, e.g. "it will eat if it is hungry" for animals. "Impossible" properties are those judged by adults to be false of all members of a category, whether known or not, e.g. "is assembled from spare parts" for animals.

A first point of comparison was between OK and IMPossible associations. For these property types, there is information in both domain-concepts and kind-concepts that either allows the association (OK) or excludes it (IMP). So we predicted that even young children would have definite judgements about these associations and that these would be consistent with adult judgements.

A second point of comparison was between FAMiliar and UNFamiliar items with STRange properties. Such properties should be rejected for FAMiliar items (e.g. cows do not eat paper). For UNFamiliar items by contrast, there would be a conflict between direct inference from a domain-concept (which would allow STRange properties) and generalisation from known kind-concepts (which exclude them). Considering that domain-concepts are known to govern many types of inference about possible or imaginary objects, we predicted that children from an early age would reject STRange properties for FAMiliar items and accept them for UNFamiliar items.

A third point of comparison was between ANimal and ARTefact items of the UNFamiliar type with STRange properties. The prediction above assumed that domain-concept information would allow certain associations that are not verified for FAMiliar items. However, there is strong evidence that children have a much richer understanding of what makes an animal an animal than of what constitutes artefacts. So we predicted that acceptance of STRange properties for UNFamiliar items would be higher for ANimal than for ARTefact items.

2.1. Method

2.1.1. Participants

We recruited our subjects from several nursery schools, day-care centres and elementary schools in the Lyon area. All participants had been in regular schooling from the age of two or three. There were 106 subjects, age ranging from 3;5 to 31;1. They were assigned to eight age groups: 10 three-year-olds (ages ranging from 3;5 to 3;11, $M=3;8$), 12 four-year-olds (range 4;0 to 4;11, $M=4;5$), 14 five-year-olds (range 5;0 to 5;11, $M=5;5$), 16 six-year-olds (range 6;0 to 6;10, $M=6;5$), 8 seven-year-olds (range 7;0 to 7;11, $M=7;7$), 12 eight-year-olds (range 8;0 to 8;11, $M=8;4$), 14 nine-and-ten-year-olds (range 9;1 to 10;10, $M=9;6$) and 12 adults (range 22;0 to 31;1, $M=25;6$). The adult subjects were undergraduate and graduate students unaware of the purpose of the study.

2.1.2. Materials and pretests

We used 72 square cards, 6.5 cm wide, with line-drawings of either animals or artefacts. Most cards were original drawings, completed by a few items from

(Snodgrass & Vanderwart, 1980). The cards were presented one by one against a white background. Of the 72 cards, 36 represented animals and 36 artefacts. In each category, half the items were familiar and the other half unfamiliar. Order of presentation was randomised.

Extensive pretests were performed to assign items to the "familiar" and "unfamiliar" types in either category, to assign unfamiliar items to one of the categories and to check whether children has a good grasp of the sentences describing properties. A set of 160 cards had been presented, as part of regular school activities, to 70 other children (10 in each age group considered), all of them from the same schools as the test subjects. Items were assigned to the "familiar" category if they were identified in the same (correct) way by all participants in the age group. Items to which no two children gave the same name or children said not to have seen before were assigned to the "unfamiliar" categories. Unfamiliar items were assigned to the ANimal category if the children produced the generic "animal" term or commented on similarities or differences between the item and known animals; they were excluded if children suggested that the item was a toy. Unfamiliar items were accepted as ARTefact items if the children suggested a generic term (e.g. "machine") or suggested a way to use the item. We also conducted a pretest for all the properties with the same group, making sure that all subjects understood the situation described by the properties, asking them to reformulate the properties themselves or imagine their consequences. The final list of properties used is given in Appendix A.

2.1.3. Design and procedure

This was a cross-sectional design with eight age groups (3-, 4-, 5-, 6-, 7-, 8-, 9- and-10-year-olds, adults). For each age group, the stimuli were in a 2 (Category) × 2 (Familiarity) × 3 (Property) design, with two categories of items (ANimal and ARTefact), two kinds of stimuli in each category (FAMiliar and UNFamiliar items), and three types of properties associated with the item: OK, STRange, and IMPossible.

The participants were all tested individually. They were presented with the 6.5-cm square cards one by one. They were not asked to name the items and the experimenter referred to all of them as "this one." For each card, the experimenter associated a property with the item, asking for example: "Now about this one, is it possible that it eats paper?" Note that the French original is less contrived than this English translation. A dislocated construction with an impersonal form ("C'est possible, celui-là, qu'il mange du papier?" litt. "Is it possible, this one, that it eats paper?") is more natural in French and more frequent in child's speech than the direct form ("Est-ce que celui-là pourrait manger du papier?" "Could this one eat paper?"). The canonical interpretation of such sentences is such that the whole proposition is modalised (Is it possible that [this one eats paper]?), which is an advantage here. We wanted to avoid a narrow interpretation of the sentence where the "could" would refer to the animal's capacities (Is [this one] [capable of eating paper]?). The experimenter checked the answer by asking the question again, gave vague but positive feedback ("OK, let us look at another one ...") and recorded the participants' responses.

Given the great number of items, the test had to be conducted in two separate sessions for the younger participants (three to five), and we introduced breaks in the experiment even for older children. Subjects who did not initially produce a judgement about a specific item, or said they did not know, were prompted again by the experimenter, insisting that this was about a possibility. When this failed (for younger children) the same stimuli were presented at a later stage.

2.2. Results

We scored results in terms of how many item + associations were accepted (i.e. judged "possible") by each participants in each cell. This was expressed as a percentage of the six pictures presented in each cell. These results were then averaged over each age group for each cell. A table in Appendix B provides the results for all cells in all age groups.

2.2.1. Omnibus analysis

We carried out a mixed 8 (Age Group) × 2 (Category) × 3 (Property Type) × 2 (Familiarity) ANOVA on these judgement results. Results for the main effects and interactions are given in Table 1.

Table 1
Results of omnibus ANOVA on participants' judgements

	MS	*F*	*P*
Main effects			
Age group	15 850	$F(7, 98) = 2.54$	.019
Category (Animal, Artefact)	357 207	$F(1, 98) = 240.6$	< .0001
Property type (OK, STRange, IMPossible)	2 283 734	$F(2, 98) = 1156$	< .0001
Familiarity (Familiar, Unfamiliar pictures)	68 813	$F(2, 98) = 50.9$	< .0001
Interactions			
Age Group × Category	2073	$F(7, 196) = 1.396$	.215
Age Group × Property Type	19 008	$F(7, 196) = 9.63$	< .0001
Age Group × Familiarity	2549	$F(7, 196) = 1.92$	.074
Category × Property Type	94 039	$F(2, 196) = 66.77$	< .0001
Category × Familiarity	11 396	$F(1, 196) = 10.89$	.0013
Property Type × Familiarity	88 536	$F(1, 196) = 71.91$	< .0001
Age Group × Category × Property Type	4599	$F(7, 196) = 66.77$	< .0001
Age Group × Category × Familiarity	1999	$F(7, 196) = 10.89$	.0013
Age Group × Property Type × Familiarity	2460	$F(14, 196) = 1.99$	.0196
Category × Property Type × Familiarity	7938	$F(2, 196) = 6.55$	.0018
Age Group × Category × Property Type × Familiarity	2765	$F(14, 196) = 2.28$	.0066

2.2.2. Planned comparisons

In this design, the omnibus *F*'s do not reveal the age-related effects on the variables of interest. So we used a series of linear contrasts to highlight (a) the difference between OK and IMPossible properties in each age group, (b) age-related trends in this difference, (c) the difference between FAMiliar and UNFamiliar items associated with STRange properties, and (d) age-related trends in this difference.

(a, b) Do children distinguish between OK and IMP properties? Are there age differences? Our assumption was that children would have no problem accepting OK and rejecting IMPossible properties, with either animal or artefact items, regardless of their familiarity. This would provide the baseline against which their performance on Strange properties could be evaluated.

In the Animal category, a contrast between OK and IMP results in each age group shows a significant difference ($P < .001$) for all age groups. However, the effect size is smaller for 3-year-olds ($r = .85$) than for all other age groups ($r > .95$). (Effect sizes are indexed as correlation, see Rosenthal, Rosnow, & Rubin, 2000, p. 9). This was confirmed by a Newman–Keuls post hoc test, which found a significant difference between 3-year-olds and all other groups ($P < .05$) and no other significant difference between the age groups. Apart from this difference, there was no significant age-related trend.

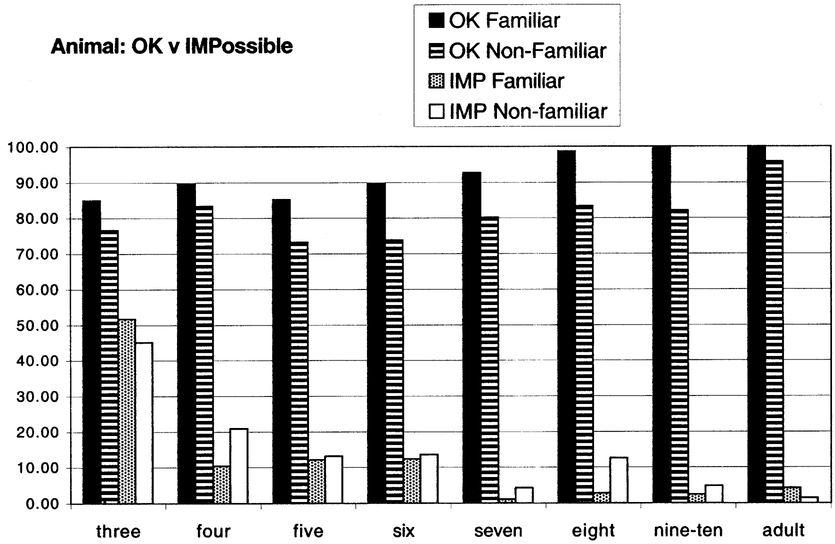

Fig. 1. Reactions to OK and IMPossible properties associated with either familiar or unfamiliar animal items. Columns indicate percentage of properties accepted by subjects of each age group.

There was no effect of familiarity. Results for the Animal category are illustrated in Fig. 1.

In the Artefact category, contrasts between OK and IMP results in each age group showed similar results: a significant difference ($P < .001$) for all age groups, a slightly smaller effect size in 3-year-olds ($r = .85$) than in other groups ($r > .93$). There was no general age-related trend or effect of familiarity. Results for the Artefact category are illustrated in Fig. 2.

Conclusion for OK–IMP difference: Subjects in all age groups consistently accepted OK properties and rejected IMPossible properties, in both the Animal and Artefact categories, and familiarity of items presented had no effect on such judgements.

(c, d) Does item familiarity affect judgements about strange properties? Are there age trends in this difference? Familiarity of items might be relevant to children's judgements of strange properties, compatible with the category but not present in any kind known to the child. So we ran linear contrasts to highlight differences between familiar and unfamiliar items with strange properties, as well as polynomial-based contrasts between age groups to highlight potential age-related trends, using adjusted λ weights for either linear or quadratic predictions (Rosenthal et al., 2000, pp. 152–156).

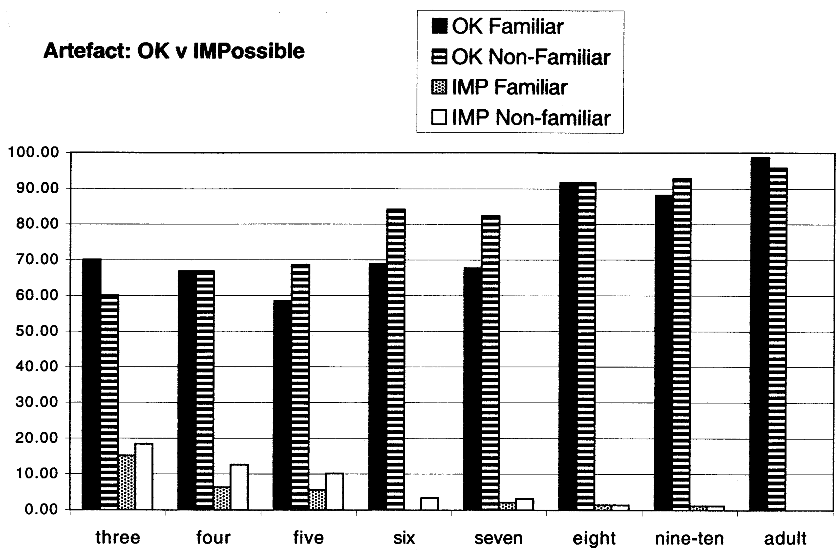

Fig. 2. Reactions to OK and IMPossible properties associated with either familiar or unfamiliar artefact items. Columns indicate percentage of properties accepted by subjects of each age group.

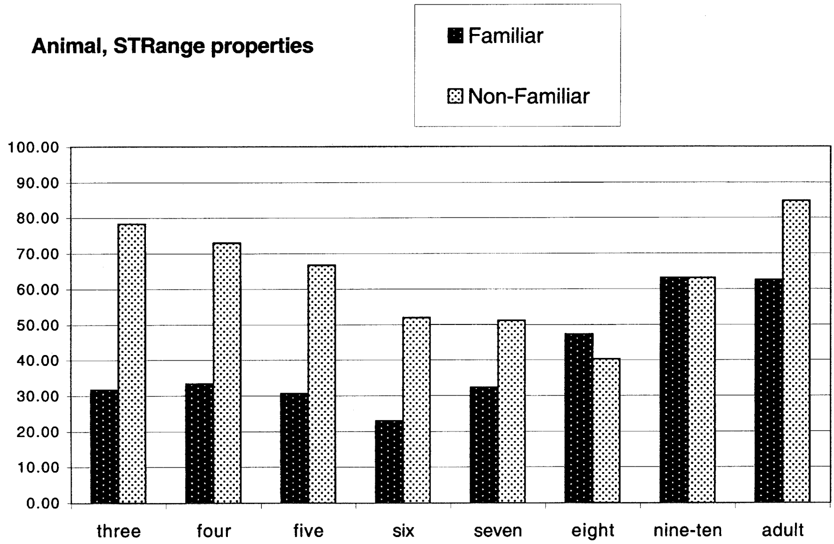

Fig. 3. Reactions to STRange properties associated with either familiar or unfamiliar animal items. Columns indicate percentage of properties accepted by subjects of each age group.

In the Animal category, subjects are generally more likely to accept strange properties if they are associated with unfamiliar items. Fig. 3 illustrates these results.

The effect of familiarity varies between age groups. Table 2 provides the results of contrasts between familiar and unfamiliar items associated with strange properties, together with effect sizes.

The raw results and effect sizes seemed to suggest that acceptance of strange properties for familiar items tends to increase with age, and accep-

Table 2
Contrasts between Familiar and Unfamiliar Animal items with strange properties, indicating *F*, *P* values, and effect sizes

Age group	*F*	*P*	*r*
3	32.66	<.0001	.88
4	10.57	.0014	.78
5	11.92	.0030	.64
6	10.96	.0047	.64
7	4.92	.0424	.49
8	0.03	.5812	.16
9–10	<0.001	.999	<.001
Adult	8.79	.012	.66

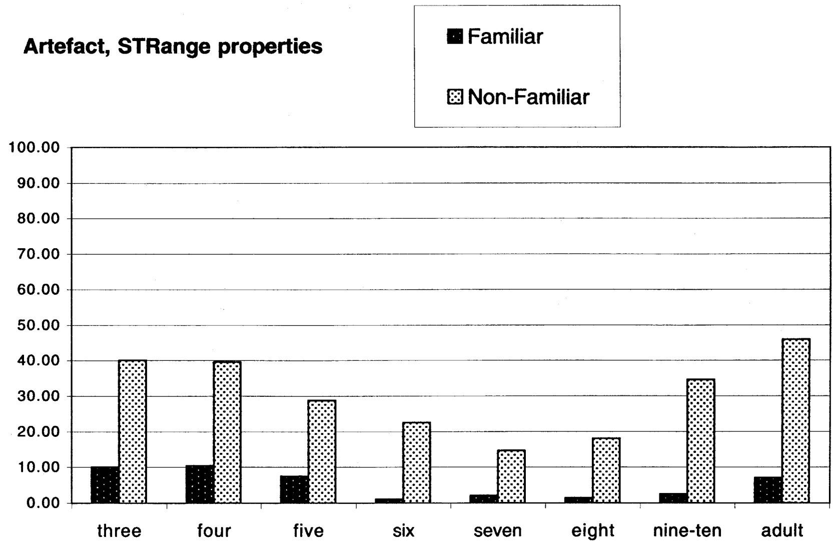

Fig. 4. Reactions to STRange properties associated with either familiar or unfamiliar artefact items. Columns indicate percentage of properties accepted by subjects of each age group.

tance of strange properties for unfamiliar items follows a U-shaped curve. Using adjusted weights for linear trends, we observed that the increase in acceptance for strange properties with familiar items was not a pure linear trend ($F<1$). However, the results for strange properties with unfamiliar items did correspond to U-shaped prediction with quadratic weights ($F=17.7$, $P<.0001$).

In the Artefact category, we found a similar pattern of differences between familiar and unfamiliar items. Fig. 4 illustrates these results.

Table 3
Contrasts between Familiar and Unfamiliar Artefact items with strange properties, with *F*, *P* values, and effect sizes

Age group	*F*	*P*	*r*
3	5.44	.045	.61
4	12.70	.0091	.80
5	16.88	<.0001	.70
6	16.98	<.0001	.72
7	7.10	.0176	.57
8	8.25	.0152	.65
9–10	16.54	.0013	.74
Adult	23.43	<.0001	.82

The effects of familiarity (significance of contrast and effect size) vary between age groups, as illustrated in Table 3.

Polynomial-based contrasts showed no significant linear trend for familiar items ($F < 1$), but a significant quadratic age-related trend for unfamiliar items ($F = 21.25$, $P < .0001$). However, note that strange properties are rejected more often than accepted for all age groups, with either familiar or unfamiliar items. What varies is the rate of rejection and the difference between familiar and unfamiliar items.

Conclusion for strange properties: Strange properties are generally more easily accepted for unfamiliar items than for familiar items. This is true in both the Animal and Artefact categories. In both categories, one observes a U-shaped curve for acceptance of strange properties for unfamiliar items. These are accepted more easily by both young children and older children or adults, and more readily rejected by middle-childhood groups. In the Animal category, young children and older subjects actually tend to accept such properties for unfamiliar items. In the Artefact category, they simply reject such properties for unfamiliar items less often than for familiar ones.

3. Discussion

Judgements about unfamiliar items tell us what properties can be extended to a whole domain, but not whether this is based on generalisation from familiar kind-concepts or on independent domain-level information. In these studies, we used "strange" properties to evaluate the relative contributions of these sources of inferences. These properties are such that they are compatible with domain-level information but not actually observed in any kind known to the child. So our participants would be led to reject these properties if they reasoned on the basis of kind-level information ("look-up table" account) and to accept them if they used domain-level information ("independent information" account). The results of the present study showed that this is indeed a reliable way of measuring domain and age differences in the inferential use of kind-level and domain-level information.

Our first prediction was that properties that are true of all kinds in a domain (OK properties) and those that are excluded by a domain (IMPossible properties) would be consistently accepted and rejected, respectively, with no age difference. This would provide both a baseline for the children's reactions to other properties and an evaluation of the effect of item familiarity. We found that OK and IMPossible properties were indeed accepted–rejected as predicted. The results were similar for familiar and unknown items. However, this effect was much smaller (but still significant) in the 3-year-olds' performance. With this latter group, we found a difference between the Artefact category, where performance was similar to other age groups, and the Animal category, where the subjects accepted most OK properties (like older children) but failed to reject the IMPossible ones as often as older children. The fact that this is asymmetrical (a bias towards tolerating IMPossible properties) suggests that the effect is not due to the length of the task or the difficulty of producing judgements of possibility, as such factors would introduce more general noise in our results. Could it be that the properties themselves were not properly understood, so that children mistook them for familiar properties of Animals? This is unlikely, for in our design, the same properties that were IMPossible for Animals also turned up as OK properties for artefacts and were accepted in this latter context. So this may point to a deeper difference between the domains. Three-year-olds fail to reject functional properties associated with Animals. By contrast, note that they do reject biological and intentional properties associated with Artefacts. This may suggest that at this age Artefact properties are not represented as valid exclusively for artefacts, while animal properties are represented as pertinent only for animals, a point we will discuss presently.

Our second prediction was that STRange properties would be judged differently, depending on whether they were associated with familiar and unfamiliar items. In particular, children should reject strange properties for familiar items more than for unfamiliar ones. For instance, their "cow" concept would specify that cows eat grass, so that the notion that cows could eat paper would be rejected. By contrast, their reaction to such properties with unfamiliar items would depend on whether they used a look-up table of familiar kind-concepts (and therefore rejected the property) or some domain-level information (and possibly accept it). We did find an overall difference between familiar vs. unfamiliar items. This was not due to a general effect of familiarity, as that factor did not have any influence on judgements about OK or IMPossible properties. The effect, however, was complicated by age and category differences.

3.1. Age differences

Reactions to strange properties with unfamiliar items seems to follow a U-shaped curve in both the Animal and Artefact domains. For both categories, then, early childhood subjects and older subjects would seem more "tolerant" of such possibilities (e.g. new animals eating paper) than middle childhood subjects. Contrary to what we expected, the accumulation of kind-concepts during middle childhood does not seem to make subjects more aware of variance within domains. If anything, this enriched database may have the opposite effect. Since there are more kind-concepts and their retrieval is easier, the "look-up table" strategy may be one that is more easily available to 8-year-olds than 4-year-olds. The latter would just not have enough kind-concepts or easy retrieval procedures, and would then use the domain-concepts by default. This, however, would not explain the important category differences.

3.2. Category differences

To say that acceptance of strange properties for unfamiliar items follows a U-shaped curve is somewhat misleading, because the levels of acceptance are so different between categories.

In the Animal category, young children from 3 to 5 years accept them (significantly above the chance level of 50% acceptance, in one-group two-tailed *t* tests, $P < .01$), then 6- to 8-year-olds perform at chance levels, then 9- to 10-year-olds and adults again accept them above chance. In this domain, then, 3- to 5-year-olds seem to bypass information from a look-up table of kind-concepts and use independent domain-level information to judge whether novel situations are possible or not. By contrast, middle-childhood subjects are influenced by their kind-concepts so that their judgements for familiar and unfamiliar items become gradually more similar. Why is this trend be reversed in older subjects, giving rise to the U-shaped curve? One possibility is that older children and adults are influenced by meta-cognitive factors, as common expectations are often defeated by school or scientific knowledge. This would be confirmed by the fact that subjects in these age groups tend to accept strange properties even for familiar items (acceptance for such combinations rises sharply after seven).

In the Artefact category, 3- and 4-year-olds are at chance levels, then 5- to 8-year-olds reject such properties, then 9- to 10-year-olds and adults are at chance level. Middle-childhood subjects are confident that strange properties for unfamiliar items must be rejected, while younger or older subjects produce mixed judgements. Here, however, it is difficult to maintain that the U-shaped trend is caused by a late accumulation of meta-conceptual knowledge about artefacts, for older children and adults are still not prepared to accept strange properties for either familiar or unfamiliar items.

We would suggest that this asymmetry in reactions to strange properties, together with the asymmetrical performance on OK and IMPossible properties, may be better understood in terms of the connections established between kind- and domain-level information. This is especially clear in young subjects. Potential properties of new animals are judged on the basis of "independent information" at the domain level, while new artefacts are judged mainly by comparison with a "look-up table" of familiar kind-concepts. Why this difference? This cannot be because young children lack general domain-level information about artefacts. Our subjects represented unknown artefacts as members of the general "artefact" class, as we had established through extensive pretests on all items; what we call "unfamiliar" artefacts here were clearly understood by all subjects as members of the same general class as forks and pencils. So it is more plausible to assume that the domain difference stems from

(a) different types of information being stored in these two domain-concepts and (b) resulting differences in the connections established between kind- and domain-concepts.

This is clearer if we consider the properties used in this study. Those described as OK for Animals (IMPossible for Artefacts) were mainly about biological and psychological functioning, in other words about typically animate, goal-directed features. The properties that were OK for artefacts (IMPossible for animals) had to do with functional properties and artificial structure (e.g. can be used for this, is made of that . . .). So when young children reject IMPossible properties for artefacts, this means that animate properties are thought to be exclusively applicable to animals and persons. When they (somewhat) tolerate functional mechanical properties for Animals, this means that such properties are not exclusively tied to Artefacts. In other words, although young children may know these properties to be actually true of various artefact kinds they are familiar with, this is not sufficient to make such properties general features of the Artefact category as such. By contrast, the fact that some features are known to be true of familiar Animals seems to trigger particular inferences that make such features true of Animals only. This asymmetry in the abstractness of information available would be confirmed by the young subjects' reactions to strange properties. Young children know that various animals eat various kinds of substances, and this variance seems to suggest a rather abstract principle, to the effect that each species has its own diet; so the suggestion that a new animal may feed on soap is accepted. By contrast, knowing that various artefacts are made of various substances does not mean to trigger such an abstract inferential principle, to the effect that new objects could be made of unexpected substances. On the contrary, children judge them by reference to a look-up table of known kinds. Inferences about new artefacts are mainly constrained by comparison with familiar ones.

This is consistent with a description of the difference between domains in terms of *causal integration*. There is strong evidence that the animal domain is causally integrated from the preschool years. That is, features that are not just associated with kind-concepts but also integrated by causal links that are generally true of the domain, and therefore readily expected of any member of the animal domain. Animals eat because they are hungry and so that they can grow; they rest because they are tired; this is because they move around; they do that in order to achieve goals. Various authors have interpreted these connections as based on projections of intuitive psychological expectations (Carey & Spelke, 1994) or of physical ones (Au & Romo, 1998), as the outcome of independent "skeletal principles" of the domain (Gelman, 1990), as a specific "mode of construal" for animacy (Keil, 1994), or as a "core theory" of the domain (Wellmann & Gelman, 1992), but it is clear that there are such connections. Our results confirm this, in the sense that these typically animate properties are not extended to artefacts, which would suggest that, in order to "get" one animate property, an object must have other animate properties. This explains why artefacts, either familiar or not, are not thought to have such properties. In this sense, some of the properties represented in each animal kind-concept can be described as parameters in general principles represented at the domain level.

One might surmise that there is no corresponding causal structure at the domain level for artefacts. Indeed, children's judgements seem to be heavily influenced by features of known concepts (hence, their reactions to STRange properties); moreover, young children sometimes accept that some artefact properties be extended to unfamiliar animals, which would suggest that there is no domain-level theory to exclude such extensions.

However, we propose that this may not be the most likely conclusion, if we replace these results in the background of other findings about artefact concepts. We know that young children do associate specific functions with artefact kinds (Gelman, 1988; Keil, 1986) and that they pay attention to functional affordances (Kemler Nelson, 1995). Older children make use of the "functionality rule" (an object counts as possible substitute for an artefact of kind X if it can be used for the same function as X) although this is found mainly in fifth and eighth graders (Richards et al., 1989). Our results would suggest that such information remains at the level of kind information. This may not be because there are no overall expectations about artefacts, but rather because these expectations are more abstract than a theory of how artefacts get their function. Recently, Petrovich (1999) has shown that preschoolers have a good grasp of the difference between natural and artificial objects in terms of origin rather than structure. They are intuitively aware of a difference between objects that can and objects that cannot be made. However, their explicit justifications tend to converge on animacy criteria (for the natural objects), which explains why in many classical studies children had difficulty classifying plants in the same category as animals. In terms of origins, however, they have no such difficulty.

To sum up, then, the artefact domain may differ from the animal domain, at least in the first years, in the following way: Animal kind-concepts are the object of causally related expectations in terms of animacy and goal directedness, so that many features of each kind-concept are parameters for principles of the animal domain-concept; Artefact concepts are the object of one very abstract expectation, namely that they are artificial in origin (Petrovich, 1999). This would mean that at preschool age each functional feature of an artefact concept remains a feature of a kind-concept rather than a parameter in a general expectation of functionality. However, by focusing on the artificial origin of artefacts, children would already have a causal framework that makes it possible to consider their creators' intentions as more relevant to kind membership than their current use (Bloom, 1996).

Finally, one may speculate on the presence of such domain differences in adult semantic memory. The difference in organisation between the animal and artefact domains is supported by a host of results from behavioural performance in implicit and explicit tasks (Ahn, 1998; Lloyd-Jones & Humphreys, 1997; Vaidya et al., 1997; Vitkovitch, Humphreys, & Lloyd-Jones, 1993), from neuroimaging (Damasio, 1990; Martin, Wiggs, Ungerleider, & Haxby, 1996; Tranel, Logan, Frank, & Damasio, 1997) and from the study of cognitive impairment (Caramazza & Shelton, 1998; Sartori, Coltheart, Miozzo, & Job, 1994). These results suggest that, in these different domains, different features are stored in kind-concepts; modalities are differently engaged in storing prototypes for kinds; neural structures that support information retrieval are themselves distinct. So the domain differences observed in our studies might stem from fundamentally different ways of constructing kind-concepts in the animal and artefact domains.

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Appendix A. List of properties associated with picture items. The actual sentences modalise the predicate, e.g., "*Is it possible that* this one has metal pieces in it?"

Animal, OK	Artefact, OK
Runs away if scared	Has pieces of metal in it
Shivers when it's cold	Was made by people
Has offspring	Has pieces of plastic in it
Moves to get somewhere else	Was mended with tools
Drinks water	Was put together with glue
Sleeps at night	Is sometimes out of use
Animal, STRange	Artefact, STRange
Eats soap	Is made of sand
Turns black when angry	Is used to break pebbles
Gets bigger at night	Starts working when you touch it
Is scared by clouds	Is made of glass
Eats paper	Can work underwater
Sleeps standing up	Is made of rubber
Animal, IMPossible	Artefact, IMPossible
Same as Artefact, OK	Same as Animal, OK

Appendix B. General table of results by cell and age group

Age group:			3	4	5	6	7	8	9–10	Adult
N=			10	12	14	16	8	12	14	12
Animal	OK	Familiar	85.00	89.58	85.18	89.58	92.71	98.61	100.00	100.00
			(22.84)*	(12.40)*	(22.06)*	(17.08)*	(14.87)*	(4.81)*	(0.00)*	(0.00)*
		Nonfamiliar	76.67	83.33	73.15	73.75	80.21	83.33	82.14	95.83
			(25.09)*	(21.82)*	(30.32)*	(21.84)*	(25.25)*	(24.62)*	(21.15)*	(10.36)*
	STRange	Familiar	31.67	33.34	30.55	22.92	32.29	47.22	63.10	62.50
			(30.88)	(25.20)	(29.84)*	(26.44)*	(16.63)*	(26.43)	(32.80)	(31.88)
		Nonfamiliar	78.33	72.92	66.67	51.88	51.04	40.28	63.09	84.72
			(35.18)*	(19.80)*	(34.30)*	(36.78)	(31.90)	(24.06)	(21.86)*	(13.21)*
	IMPossible	Familiar	51.67	10.42	12.04	12.29	1.04	2.78	2.38	4.17
			(26.59)	(23.47)*	(20.46)*	(22.50)*	(4.17)*	(6.49)*	(8.91)*	(10.36)*
		Nonfamiliar	45.00	20.83	13.15	13.54	4.17	12.50	4.76	1.39
			(32.44)	(30.54)*	(22.59)*	(26.68)*	(9.62)*	(28.54)*	(10.19)*	(4.81)*

Appendix B *(continued)*

Age group:			3	4	5	6	7	8	9–10	Adult
N =			10	12	14	16	8	12	14	12
Artefact	OK	Familiar	70.00	66.67	58.33	68.75	67.71	91.67	88.09	98.61
			(29.19)*	(28.17)	(24.42)	(26.44)*	(30.10)*	(11.24)*	(13.76)*	(4.81)*
		Nonfamiliar	60.00	66.67	68.52	84.16	82.29	91.67	92.86	95.83
			(40.21)	(34.50)	(29.09)*	(21.52)*	(22.33)*	(13.29)*	(14.19)*	(10.36)*
	STRange	Familiar	10.00	10.42	7.41	1.04	2.08	1.39	2.38	6.95
			(21.08)*	(17.68)*	(19.15)*	(4.17)*	(5.69)*	(4.81)*	(8.91)*	(8.58)*
		Nonfamiliar	40.00	39.59	28.70	22.50	14.59	18.06	34.52	45.83
			(35.31)	(26.63)	(28.47)*	(23.49)*	(15.96)*	(22.98)*	(28.09)*	(29.41)
	IMPossible	Familiar	15.00	6.25	5.56	0.00	2.08	1.39	1.19	0.00
			(25.40)*	(12.40)*	(11.43)*	(0.00)*	(5.69)*	(4.81)*	(4.46)*	(0.00)*
		Nonfamiliar	18.33	12.50	10.18	3.33	3.13	1.39	1.19	0.00
			(25.40)*	(29.21)*	(20.72)*	(7.20)*	6.72)*	(4.81)*	(4.46)*	(0.00)*

NB: These results are broken down by age group, category, property, and familiarity. Figures are average performance of age group in cell, measured as the number of item + property associations accepted as "possible." So a score of 89.58 on the ANimal, OK property, Familiar cell in the 6-year-old column means that 6-year-old participants, on the average, accepted 89.58% of the associations between a familiar animal and an OK property. The figures inside parentheses are standard deviations for each cell.

* Indicates a significant ($P < .05$) result for a one-group t test, against a chance level of 50% (half yes, half no).

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