

Categories and levels of information

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INTRODUCTION

It is a truism that we all must lump entities into equivalence classes if we are to make any sense of the world around us. It has also generally been acknowledged that there is a potentially infinite number of ways in which we could treat a class of things as equivalent. However, an important issue that has not yet received ample attention is a systematic consideration of the levels at which our conceptual representations might originate. By the time we become adults, we routinely think about classes of things that seem to encompass far more complex relations than any kind of perceptual similarity alone. Tools, vehicles, and living kinds are universal examples, as are classes of intangible things such as odd numbers, puns, or riddles. No one doubts that we are readily able to think about these classes of things, or that we use them in many kinds of everyday reasoning. However, there remains an enormous debate over how our knowledge of such classes emerges in development, and how this knowledge is neurally instantiated.

In this chapter, we will consider an integrative approach to these questions. The traditional approach has been to assume that perceptual features are more basic to categorisation than conceptual ones. In contrast, here we will argue for a framework in which the default assumption is that multiple levels of information are used to distinguish categories in the world, and that no one kind of feature, perceptual or conceptual, is privileged

developmentally.¹ We will suggest that taking a more synthesised perspective that links research from developmental, neuropsychological, individual difference, and comparative viewpoints can clarify how we use these different levels and how we might distinguish them empirically.

A HETEROGENOUS WORLD AND THE PLURALITY OF SCIENCE

Surely the most intense and systematic efforts to make sense of the world arise from the actions of a formal scientific discipline and its practitioners. Although it is possible that the ways in which the formal sciences proceed and carve up the world might be quite different from how individuals make sense of their world at a more intuitive and informal level, recent discussions suggest that the similarities could be more striking than the differences. It appears that everyday science is not nearly as formal and logically structured as was traditionally thought. In fact, science is characterised by hunches, gaps, and serendipity (Dunbar, 1994), making the distance to intuitive theories seem quite small. Thus, thinking about how scientific theories and thought are structured might give us useful clues regarding how people's naive theories and conceptual thought are accrued.

Given the putative similarity between naive theories and scientific enterprise, recent radical shifts in the philosophy of science have significant ramifications for how all of us might make sense of the world. First, there has been general acquiescence that reductionism is unlikely to succeed as a way of doing science. Even when it might be possible to state the laws of one science, such as cellular biology, in the terms of a more molecular level, such as organic chemistry, it is clear that the ability to execute the science of biology solely in terms of the language of organic chemistry is likely to be such a cumbersome and unwieldy exercise as to be cognitively and computationally impossible (Salmon, 1989). Moreover, this example of cellular biology versus chemistry takes near neighbours with an intuitively plausible theoretical connection; the matter becomes much more complicated in trying to explain, say, cognition in terms of physics (Fodor, 1975).

The failure of reductionism has naturally led to the question of whether the nature of explanation is the same in all the different levels of science. That is, do explanations at these different levels seem to have the same kinds of structural principles, and do they incorporate the same kinds of causal relations? This is a surprisingly recent area of inquiry but the repeated conclusion

¹It might be argued that it is difficult or impossible to distinguish the perceptual from the conceptual at some level of analysis. However, for the purposes of our arguments, they are readily distinguishable within the broad range of features we refer to: low-level perceptual to high-level conceptual (i.e. theory of mind).

seems to be that the different levels of science do indeed vary in their structural and relational properties because they track different kinds of entities in the world. Thus, the current shift to more realist approaches in science (Boyd, 1999) embraces the idea that different patterns of regularities in the world might require different kinds of theoretical structures to best understand them. From this standpoint, it is clear that the differences among the theories are highly abstract and cannot be sufficiently stated solely in terms of perceptual features. Biological theories might be contrasted with those of physical mechanics because they usefully employ teleological arguments. Cognitive theories may be distinguished from both biology and mechanics because of their reference to beliefs, desires, and computational states. If the theories of various disciplines constitute different domains of thought, and if the concepts and designated categories within these theories inherit many of the distinctive properties of the theory in which they are embedded, then important differences among such classes of concepts will include highly abstract cognitive, not just perceptual, differences. In this way, underlying explanatory structures may manifest themselves in intuitive scientific theories that both lay people and the scientific establishment use to successfully understand concepts within domains like mechanics and biology.

Thus, it seems reasonable that, as adults at least, we have many intuitive theories that are organised in ways that resonate best with only some patterns in a heterogeneously structured world. Moreover, these theories are important to understanding how we cluster things into the same classes. The theories tell us which features to weigh as relevant and how much to weigh them in categorisation (Ahn, Kim, Lassaline, & Dennis, *in press*). We assess similarity with respect to our theories of what properties matter and why (Medin & Shoben, 1988). Some have argued that the need for theories of a heterogeneous world has led to the need for an "adapted mind", such that the cores of naive theories were naturally selected for over a period of evolution (Cosmides & Tooby, 1994). A critical research question stemming from this argument centres around the extent to which our minds do need to be biologically adapted in this way, and at what level of processing. The debate has been sharpened in recent years by a surge of research on category-specific impairments, those patterns of brain damage that lead to difficulties in thinking and talking about broad categories such as animals or tools. The implication of such research, of course, is that there exists some sort of specialisation in the brain for domain-specific categories. The debate concerns the nature of that specialisation. In a recent review, for instance, Humphreys and Forde (*in press*) argued that the underlying neural substrate cannot be understood as arising from only one level in the cognitive system. In this way, the distinction in deficits cannot be captured simply by a sensory versus non-sensory description. Instead, they proposed that such difficulties could involve possible deficits at several different levels that are hierarchically organised and highly

interactive. Importantly, they argue that there is a large role for "re-entrant processing". Here, objects initially activate structural descriptions and associative/functional knowledge in memory. Then top-down processing proceeds to the perceptual level which allows the object to be discriminated from other entities. This allows name retrieval to occur. Damage at any point in the pathway can lead to differential deficits in categorical knowledge about living and non-living things depending on the reliance of those categories on perceptual versus functional features.

Indeed, there is a broad continuum of processing levels at which category-specific impairments might occur, ranging from low-level percepts to high level cognition. The immediate question, then, is at what level or levels we have these domain specific specialisations. Obviously, this is an extremely complicated question and, for the sake of clarity, we will first approach it by considering two examples of category-specific impairments: artefacts and animals.

LEVELS OF DOMAIN SPECIFICITY

Generally speaking, some individuals with particular areas of brain damage appear to have deficits in the ability to think about artefacts such as tools. Conversely, others, with different lesions, have difficulties thinking about animals (whether these labels encompass the precise range of these categories will be discussed later on). To begin thinking about how our conceptual representations of tools and animals might be differentially impaired, one must first consider all the ways in which tools and animals might tend to differ. That is, what are the informational and structural differences between the two that may have representational consequences? In terms of low-level vision, there might well be differences between the two in patterns of spatial frequencies, wavelength functions, and in the extent to which contours are constructed by irregularly shaped fractals (presumably, this last alternative would apply more to animals than to tools). At mid-level vision, there are differences in texture, edge junctions, and perhaps even in the distributions of the most typical primitive geons. Furthermore, there are differences between tools and animals in typical colour distributions.

Similarly, at high-level vision, there are a host of possible differences including overall shape, axis of symmetry (for instance, animals might have bilateral symmetry around a vertical axis more frequently than do artefacts), and particular feature configurations (for instance, faces). Furthermore, there could also be statistical differences between animals and tools with regard to how frequently certain types of perceptual features occur in each. Living kinds might tend to have a larger collection of texture types than most artefacts (i.e. an average animal has a larger set of different textures than an

average tool) whereas artefacts could have larger set of possible perpendicular surfaces and edges. Such disparities at the perceptual level could form an informational basis for having different categories.

There are also rich interactions between these things that can distinguish the two. One such interaction might be that of colour patches and part boundaries or limb junctions. Colour patches in artefacts are more likely to break neatly at part boundaries than are colour patches in animals. In animals, it is not common for there to be a discrete colour-change line between limbs and body. In contrast, this is quite common for similar limb-like protrusions in vehicles, furniture and tools. Interactions between mid-level and high-level vision could also provide cues to category membership. In the extreme, one might imagine that an animal that did have such distinctive colour changes at its joints and a smooth texture might be mistakenly judged as an artefact (such as a toy or robot) by a naive observer viewing a static display. Similarly, seeing a hairless cat like a sphynx always provokes surprise and indignation, and sometimes complete denial of its membership in the cat category at all, as it violates perceptual "requirements" for animals as having a fuzzy texture that is continuous between the limbs and body. Certainly, when one mixes perceptual features at one level with features at other levels (i.e. functional features), there are vastly more ways to distinguish the two categories.

Thus far, we have described only static perceptual differences, but there are many dynamic ones as well. Cutting (1986) has shown that rigidity of limbs and their motions around joints look very different for moving artefacts and animals, as do the typical centre of gravities as inferred from their motions. If one attaches point lights to various parts of moving artefacts and living kinds, even for relatively small numbers of such dots, there are significant differences in both the patterns and timing parameters of movement (Cutting, 1986). For instance, the time of action and reaction seems different for the two categories. For many mechanical systems, movement of one bounded solid causes immediate consequences when there is contact with another, such as in the launching effects documented by Michotte (1963). In Michotte's experiments, a circular disk approaches another at a constant velocity and then suddenly stops adjacent to a second disk, which then starts moving off along the same path at the same or a somewhat reduced velocity. Adult subjects report not just seeing the contiguity but the powerful impression that the first disk 'launched' the second one by transmitting a force through the collision. The effect disappears, however, when the delay between the stopping of the first disk and the starting of the second becomes appreciable. Subjects still notice the contingency relations just as strongly, but they do not have the compelling phenomenal experience of seeing the first disc causally launch the second.

For animals, there might be much longer delays between cause and effect.

Likewise, categorising simple geometric forms as intentional or agential in Heider and Simmel's (1944) dynamic perceptual arrangements is an almost unavoidable consequence of viewing the display. The Heider and Simmel displays involve plane figures such as circles, squares, and triangles moving in contingent ways that suggest not just social actions in general but specific social roles such as aggression, fear, and friendship. Even 12-month-olds attribute rational action to a ball that they had previously seen expand and contract as though it were respiring, and interact with a second ball in a contingent manner (Gergely, Nadasdy, Csibra, & Biró, 1995). Such compelling dynamic cues involving intricate, and in many ways social, timing might similarly distinguish animals from artefacts or tools. It is at this dynamic perceptual level that considerations of differences between animals and artefacts often stop. There are, however, many more differences that continue at higher levels. These differences could, in fact, be just as salient to very young children as many of the lower-level perceptual ones.

The range of possible higher-level differences is extensive and is discussed in more detail elsewhere (Atran, 1996; Keil & Richardson, 1999), but a few key contrasts here will illustrate the point. Some differences revolve around the relative roles and locations of essences for the two kinds, others around causal patternings among component properties, others centre on paths of origins, and still others around patterns of variation across exemplars. We will consider the first two differences here.

First, consider the notion of essences. The idea of essences seems to be very different for artefacts than for animals. Some have suggested that artefacts do not have any essence at all (Keil, 1989), while others (Bloom, 1996) suggest that there is an essence for artefacts but that it should be understood as one that involves the intention of the creator of the artefacts. Either way, we seem to envision the critical nature of the two kinds as very different. For animals, there is the notion of a fixed kind of substance inside that makes each kind distinct, today frequently conceptualised as DNA. Tiger DNA is the essence of tigers, and wombat DNA the essence of wombats. This folk notion is really a probabilistic distribution of DNA types for natural selection, because the notion is wrong if one thinks of a specific sequence of DNA that spans across all members of a species. Correct or not, however, it could be a foundational way in which we understand living kinds as different from artefacts. Of course, DNA is a recent concept, but essentialism, a belief in some inner fixed entity that is causally responsible for each species, is as old as written history. In other cultures, and in earlier times, the essence of a living kind could have been seen as a vital force or an organ, but the notion of essence itself recurs frequently. In fact, some have argued that humans' naive essentialist bias presented a powerful cognitive bias against coming up with the idea of evolution by natural selection, an idea that only emerged with the

writings of Darwin and Wallace in the mid-nineteenth century, despite millennia of selective breeding of plants and animals (Hull, 1965).

The appreciation of essence emerges very early in children as well (Gelman & Hirschfeld, 1999; Keil, 1989). For instance, seven-year olds but not five-year olds know that natural kinds conserve their identity over transformations whereas artefacts can be changed from one kind to another with a few alterations in physical structure (e.g. turning a table into a bookcase; Keil, 1989). Further, by 8 years of age, children come to know that animals and machines have different internal component structures (Simons & Keil, 1995). However, it is not known just how early essentialist realisations emerge. There are, to date, no studies on the expectations of very young infants' about essences of animals versus artefacts, and it is not entirely clear how this understanding could be tested. Likewise, we also do not know whether it is learned at all, or if it appears independent of experience. The important point in highlighting this developmental trend, but also in pointing out the dearth of infant research, is simply to suggest that it could give some insight as to what kinds of information might be more basic than others in structuring categories. This is certainly true in the case of reasoning about essences. Perhaps the key message of late from developmental research is that developmental patterns do not seem to follow a strict progression from perceptual to conceptual (see Keil, Smith, Simons, & Levin [1998] for a recent argument). This, in turn, raises questions about what would be core components of adult knowledge. If the idea of essences is indeed universal across all cultures, then it could well be an intrinsic way in which we organise some concepts. We might (although not necessarily consciously) look for essences in most kinds that we encounter and then, depending on whether we sense one at work, we might organise the relevant category in a distinctive way. Or, to put it another way, we might evaluate the origin of the essence as being internal to the organism or external to it (as might be the case for artefacts) and from this assess its artefact/natural-kind status.

To broaden the discussion, consider a few other alternatives. We could attribute intrinsic, non-intentional needs to all living kinds in ways that we do not to artefacts. A flower needs sun and water to survive, and a person needs food, water and shelter to survive. An artefact, however, does not have intrinsic needs. Rather, an intentional agent needs to supply things to some artifacts to have them perform a needed function. Perhaps the ability to see what entities need in their own right is necessary to having a coherent living kind concept, but not to having a coherent concept of most artefacts. Similarly, one could also consider the significance of teleological or functional characteristics when categorising artefacts and natural kinds. Asking what a particular characteristic is "for", that is, ascertaining the purpose of features such as a pointed surface of a rock versus the hide of a dinosaur, or the green colour of a plant versus that of an emerald, might or might not be

appropriate given the domain of reference (Keil, 1994; Kelemen, 1999b). Moreover, such a distinction might further differentiate categories of biological and non-biological natural kinds. Indeed, a debate has arisen regarding the importance of functional relations in reasoning about artefacts and natural kinds, particularly in terms of whether such reasoning spans many domains or is specific to biology and artefacts (Keil, 1994; Kelemen, 1999a). The debate concerns the origins of teleological reasoning and how it is mapped onto domains, with some research (Keil, 1994) suggesting that even four-year olds know that teleological expressions fit better with aspects of biological kinds than with other non-living natural kinds, and other research (Kelemen, 1999a) suggesting a much broader and often inappropriate mapping of teleological explanations onto other natural kinds. As this issue becomes resolved, it will help explain how teleological reasoning comes to be involved in organising natural kind and artefact category membership.

Second, there are more elaborate networks of causal patternings that distinguish living kinds and artefacts. The causal patternings of artefacts and living kinds differ fundamentally in that molecular features tend to cause functional features in living kinds, but functional features tend to cause molecular features in artefacts (Ahn, 1998). For instance, Ahn has used the example that in birds, the feature of "having wings" is what enables the bird "to fly", but in chairs, the feature "you sit on it" is the reason why it is "made of solid material" (and not made of something like gelatin). Differences in causal patternings might also distinguish several other kinds as well, including intentional versus mechanical agents, vehicles versus tools, and predators versus prey. These differences might be located either roughly at the same processing level, or at higher and lower levels.

Furthermore, causal patternings have a significant impact on how we categorise. One specific way in which this occurs has been reported by Ahn and Kim (2000) and Ahn et al. (in press), who demonstrated that the more causally central a feature is, the more important it is in categorisation. For instance, if people think that a novel animal called a rooban eats fruits, has sticky feet, and builds nests in trees, and that these features are not causally connected, they treat each of these features as equally important in categorisation. However, if they are instead told that sugars in the fruits are secreted through the pores of the roobans' feet, giving them sticky feet, and that these sticky feet in turn enable roobans to climb up trees to build their nests, people then treat these features differently in categorisation. Specifically, they treat the most causally central feature (eating fruits) as most important in categorisation, the causally intermediate feature (sticky feet) as next most important, and the terminal effect feature (build nests in trees) as least important. This effect of causal status has been demonstrated robustly in the domains of both novel and real-life animals, plants, artefacts, mental disorders, and other social categories, using a variety of measures including free sorting,

categorisation of transfer items after learning novel categories, and judgments of typicality and conceptual centrality (Ahn & Kim, 2000; Ahn et al., in press; Kim & Ahn, in press; Sloman, Love, & Ahn, 1998). Thus, our ability to distinguish general types of causal patternings for different domains significantly influences the way we categorise new exemplars and think about categories.

It is apparent, therefore, that many distinct levels can informationally distinguish categories, ranging from simple sensory properties to richer perceptual structures to complex causal patterns that predominate in a domain. The ability to detect and utilise all (or at least most) of these levels is likely to be present in humans early on in life, suggesting that they might all be fundamental to domain-specific processing. Humans, even very young ones, might be made aware of at least some of these differences and could use them to tell the two classes apart (Mandler, Bauer, & McDonough, 1991; Mandler & McDonough, 1993). Moreover, it is not obvious that the lowest sensory level is privileged either developmentally or in the course of processing (see Chapter 11). That is, to some extent all levels might be present early on (Keil et al., 1998). Thus, there is a broad continuum of processing levels at which domain-specific specialisations seem to occur early on in development, ranging from low-level percepts to high level cognition. To probe further into our initial question of determining the levels at which domain-specific processing occurs, we turn now to the contributions and impact of nativist and empiricist approaches to developmental examinations of conceptual structure.

NATIVISM, EMPIRICISM, AND CHANNELLING

We have suggested that there seem to be a great many kinds of information that we can use to be far better than chance at telling not only animals and artefacts apart, but also to make distinctions within many other higher level categories, such as intentional agents, plants, and vehicles. Moreover, adult humans probably have access to most or all of these levels. A contentious issue arises, however, when we ask about what kinds of information are central or peripheral to the mental structures and processes that are involved when we think about such categories. The answer to this question is by no means straightforward. It is possible that some informational patterns, which seem, at first glance, distinctively associated with a category, play only a minor role in influencing thought about members of that category. The crucial point here is that we want to ascertain the structural relations between levels of information both in terms of real-time thought and in terms of how developing humans first distinguish animals and artefacts. Lurking beneath the surface of many of these debates is the nativist/empiricist controversy and the ways in which scholars ally themselves with one side of the debate.

First, however, we need to clarify exactly what this debate is about. One

way to understand the nativist/empiricist debate is in terms of domain specificity and levels of processing (Cowie, 1999; Keil, 1994, 1999). Both sides agree that humans are biologically endowed with structures and processes that are needed to help them make sense of the world around them. Something intrinsic to us and not to the crib enables us to learn. Moreover, something intrinsic to us enables us to learn differently from other living creatures. Humans learn things that other species either cannot learn at all or learn at a much slower rate. None of this should be the least bit controversial, so it is puzzling to read discussions attacking nativists as arguing that humans are unique and empiricists as arguing that we are just like other species. No one would deny that in some respects we clearly are unique, whereas in others we are not. It is in the details of those dimensions of similarity and detail that the nativist/empiricist debate resides.

The primary difference between the two views involves an interaction between level of psychological operation and specificity for kinds of information. Again, both nativists and empiricists agree that we come into the world with structures and processes innately tailored to certain patterns of information. We obviously agree, for example, on the existence of sensory organs, such as eyes and ears, that are clearly structured in ways to be sensitive to only certain kinds of information and not others. We all acknowledge that other species have sensory organs that might differ from others in this respect, whether it be the sensitivity of bees to ultraviolet light, the sensitivity of bats to some sound patterns, or the vomeronasal sensory organ of the rat (Halpern, 1987), which is sensitive to large molecules that seem halfway between taste and smell.

The difference in opinion arises when we move "upstream" from the sensory receptors and ask about information specialisations in higher-level structures and processes. The whole notion of upstream is an oversimplification, given the rich feedback connections from "higher" levels back down to lower levels, as well as lateral pathways within a level (Van Essen, Anderson, & Felleman, 1992; Van Essen, Drury, Joshi, & Miller, 1998). None the less, there is, generally speaking, a hierarchy of higher and higher levels of processing as one moves inwards from the sensory receptors (an extremely simplified example might be the visual information pathway from sensory receptors to the lateral geniculate nucleus (LGN) to primary visual area V1 to the higher-level visual areas of V2, V4, and so on). Nativist/empiricist controversies become intense as theorists try to specify the nature of domain specialisations in terms of level and the kinds of information for which the specialisations exist. Empiricists might argue that sensory levels of processing are most basic, and that there exist early neural specialisations only for more primitive forms of information. Nativists, on the other hand, might argue that higher levels of processing are fundamental, and that there exists early neural specialisations for more complex cognition.

What evidence is there for each side of the debate, framed in this perspective? It seems that at the very least we have specialisations for information that is more high-level than the lowest-level sensory input. For example, specialisations for light-related information continue far up into visual cortex, becoming only questionable when multimodal neurons arise in the neural architecture. There are also specialisations that result in categorical perception, such as those for colour, which are present from at least 4 months of age (Bornstein, Kessen, & Weiskopf, 1976). Thus, we have specialisations not only for a particular form of energy, such as light versus sound, but for particular parts of an energy continuum. Such specialisations result in the ability to categorise or subjectively parse apart colours from an otherwise continuous range of visible wavelengths, speech sounds, and tones, among others. Moreover, it is now widely agreed that information specialisations are often tailored to distal as opposed to proximal patterns in the world. That is, Gibson (1950) argued that we perceive objects, surfaces, and layout, not just stimulations on the retina or eardrum. This requires higher level perceptual processing, which integrates a variety of types data from the sensory environment. This is certainly beyond the functional capacity of retinal ganglion cells in the visual system, for instance. Indeed, evidence suggests that we have neural structures in what is known as mid-level vision, tailored to perceive surfaces, objects, and occlusions (Nakayama, He, & Shimojo, 1995).

In principle, it is possible that specialisations for information might exist at all levels of processing. To return to the example of animals versus artefacts and the role of timing and teleology, it is possible that our ability to tell them apart emerges not just from picking up perceptual differences but also differences in their causal patternings. We might have a collection of expectations about things that act on each other at a distance or with certain time delays characteristic of intentional agents (Csibra et al., 1999; Heider & Simmel, 1944), which are sharply distinct from our expectations concerning the more immediate spatial and temporal continuities of mechanical objects. We might also expect that animals as a whole have no functional purposes, whereas their parts do (except for domesticated animals, which might be viewed as somewhat artefactual). By contrast, we do think that artefacts as a whole have purposes. There is an abundance of such possible expectations, many of which might be interconnected and interdependent, in a network that constitutes an intuitive "theory" of living things. We have been careful not to call this "theory" a network of beliefs, because it is not clear that they are necessarily explicit beliefs so much as they are implicit expectations that guide how we interpret the behaviours of living things. Most adults may have never consciously realised that they do not expect animals as a whole to have a purpose in the ways that artefacts do, but they might nonetheless show that knowledge daily in the ways they ask questions about, and behave towards,

the two kinds. In sum, the possibility exists that we may well have information specialisations at all levels of processing.

THE LOW-LEVEL PERCEPTUAL SHUNT AND "ENLIGHTENED EMPIRICISM"

Before speculating further upon this point, however, we must consider an intriguing empiricist argument about the origins of high-level domain-specific circuits (and even discrete areas of neural tissue) dedicated to processing only some kinds of information. Its most explicit form is often discussed in reference to face perception. Here, a "low-level perceptual shunt" is thought to result in higher levels of domain specificity. Moreover, it is proposed that there exists only a low-level perceptual specialisation at birth, which becomes more developed over time and with experience (an example is discussed in detail later). Such accounts are in accord with what some have argued to be the new "enlightened empiricism" (Cowie, 1999). It is useful, therefore, to consider in some detail how this case might be extended to conceptual domains. Ultimately, we want to ask if it is possible empirically to distinguish such enlightened empiricist hypotheses from nativist ones.

As introduced earlier, perhaps the most lucid proposal of a low-level perceptual shunt has been offered for faces (Johnson & Morton, 1991). A young infant is assumed to have a neural circuit that is specialised for faces, but only in the crudest sense. The circuit, in fact, might be little more than a simple detector for three blobs forming an inverted triangle (two eyes and mouth). According to this model, early on, this detector might only be activated when the triangle is moving, as it would be on the face of an infant's caretaker. Empiricists grant that this much must be built in from birth, but their story thereafter diverges dramatically from a nativist view. The infant might have a region of its cortex, perhaps the fusiform gyrus, that is initially organised no differently from many other regions of cortex. This particular region, however, is the only area of cortex to which outputs of the "triangle tracking system" are sent. Over time, because it is receiving visual information about faces and little else, this region of cortex comes to organise itself in ways that are specifically attuned to faces. Eventually, they argue, a specific brain region becomes specialised for face processing. It shows "activation" to face stimuli in fMRI studies, and face processing degenerates if it is damaged.²

²In fact, the literature on face perception has turned out to be much more complex than this account, both in adult neuropsychology studies (Farah, 1994; Kanwisher, Stanley, & Harris, 1999) and in developmental studies in infants (Dannemiller & Stephens, 1988; Easterbrook, Kisilevsky, Muir, & Laplante, 1999). However, the key point here is to show how domain-specific organisation, even to the point of dedicated neural circuits in a certain area of brain tissue, could result from a system whose initial biases were only to track upside-down moving triangles with a certain spatial frequency.

Consider now how this sort of approach might be extended to other areas of perception and, more critically, to cognition. One of the most striking cases involves the category of sentient beings (for most of us, that means other people). What is often called folk psychology or theory of mind is, in adults, a body of knowledge about the category of things with beliefs and desires. Although there might be no cases of adult brain damage that lead to specific deficits in this area, there are clear cases of a selective theory of mind deficit in people who are autistic. There is also a smaller but none the less clear deficit in more verbal individuals with Asperger's syndrome. It is usually supposed that these individuals have a congenital, if not genetic, deficit in a specific brain region or system dedicated to thinking about mental states (Frith & Happé, 1998). There is, however, another possibility that builds on the perceptual shunt idea, taking a developmental perspective. Suppose there is no region of cortex that has any specialisation for mental states from the start, but that there are instead specialisations of simple, perceptual properties that are merely correlated with a goal-directed creature. These simple, perceptual properties might include motions of bounded objects that interact with each other with certain temporal delays, or which emit sounds in an alternating contingent fashion, or objects that move in a way that is contingent on the infant's own actions. The perceptual shunt model assumes that young infants do not "know" that these features are correlated with mental beings. Instead, it assumes that infants simply have a tendency to track these objects and, when they do, information about these objects is shunted either to a particular dedicated piece of neural tissue or a dedicated circuit that is more globally distributed. In this model, evolution did not prewire the child with any notions about beliefs and desires, but it did prewire the infant to track objects that manifest perceptual features correlated with mental entities. It also prewired a disposition to shunt this information to a special neural area and/or circuit, which receives input consisting of only this sort of information, albeit not having any *a priori* specialisation for it.

To date, we do not have enough evidence to tell us if this account is correct, but there are good reasons to believe in the claim that there are specialisations for noticing certain timing contingencies. For instance, if an infant makes a noise and an object makes a noise back in a contingent fashion, the infant will take special notice of the object. By at least 8 months, and possibly earlier, if such an object suddenly turns 90 degrees, infants will turn their heads to see where it is "looking", even though the object has no eyes or face (Johnson, 2000; Watson, 1985). Even the abilities of newborn infants to imitate could be related to the cyclic nature of their having been shown the behaviour by an adult or older child. Sticking out one's tongue once to an infant rarely elicits imitation. Rather, if one shows repeated tongue protrusions while looking at the infant, imitation is much more likely to emerge (Meltzoff & Moore, 1977, 1989). Thus, right from the start, certain

contingencies associated with social beings might attract the attention of the young infant.

For such accounts to represent the strongest possible forms of empiricism, one might attribute to the infant a special sensitivity to only the lowest level perceptual cues that are reliably correlated with social beings. To explain any patterns of higher-level specialised brain regions or circuits for thinking about other minds, one might then append the idea that when these low-level perceptual features are noticed, they trigger a shunting of the input to a brain region with no *a priori* specialisation for that information. We can postulate that it might be viable for the case of a naive folk psychology because, as we have been describing, there are now several studies showing a special sensitivity in infants for perceptual information that is distinctively associated with intentional beings. The perceptual shunt and more nativist proposals start to make different predictions here with respect to autistic children. The perceptual shunting view would predict that infants who become autistic would, from the start, have a deficit in the ability to detect perceptual features that are distinctively associated with intentional agents. By contrast, nativist views allow for the possibility that such infants would be completely normal in their sensitivity to the perceptual cues but would have difficulties in making cognitive interpretations of those cues.

Might this shunting account also be viable for the development of different kinds of cognition? It seems plausible to us that it might well be. One might speculate that there are indeed special perceptual triggers for liquids that lead to specialised beliefs about how this set of non-solids behaves. Perhaps there are triggers for artefacts (such as smooth edges or colour junction correlations) that shunt to brain regions that become specialised for them. So also for living kinds. To reiterate, the idea here is that infants could start with unspecialised neural tissue that, in itself, is receptive to many sources of perceptual data. Furthermore, data can only enter the system if it sets off primary perceptual triggers. It is only through the process of funnelling input to specific brain regions that higher-order calculations can be made about the complex relations between the various parts of the entities (whether this be timing, contingencies, or feature arrangement like the colour junction correlations mentioned above). As time and experience progress, similar perceptual data builds upon itself and becomes manifest in increasingly sophisticated "cognitive" category determinations. In this way, perceptual categorisation fosters the growth of conceptual categorisation.

What, then, is a more nativist alternative to such a model? The nativist view might agree that certain perceptual features are especially attractive to infants, but rather than concede that this perceptual input is shunted to a specialised region of the brain, a strong nativist view would have this input "trigger" a set of *a priori* cognitive expectations about relations in a domain. For example, seeing a certain pattern of temporal contingencies might trigger

a set of explicit expectations about the object's having goals and desires, and how these goals and desires are related to actions. Alternatively, the strong nativist view might say that when an infant sees that something is graspable and has certain textures, this perception may trigger an artifact/tool set of expectations that leads to questions asking what the object is "for" in a teleological sense. In the extreme, various perceptual triggers might lead to detailed beliefs about objects in a domain, but few such proposals are advanced today.

A somewhat more modest nativist model might also see a rich network of cognitive interconnections that are triggered by perceptual input, but would be more agnostic about how close those interconnections are to beliefs. As we mentioned above, if an object makes responsive beeps to an infant's vocalisations that are contingent in ways that suggest a social interaction, the infant will assume that the object is facing the infant, even though the object has no facial features. When the object then turns 90 degrees, the infants turn in the same direction, as though to follow the object's "gaze" (Johnson, 1998; Watson, 1985). This pattern of "gaze" following has been demonstrated in 8-month-old infants, but could plausibly be shown in much younger children, pending the invention of age-appropriate methodologies. Assume, for a moment, that "gaze" following has been demonstrated in infants so young that it could not plausibly have been learned. In this case, there might exist in the infant a set of expectations that entities respond with certain contingency and timing relations. These expectations might be that the entities have fronts, that those fronts are oriented towards the individual whose sounds are being responded to, and that if the entity rotates, its attention has been shifted in the direction that its front is now facing, presumably to something it has found interesting. Admittedly, that pattern of expectations suggests that an infant has beliefs about other mental entities and their mental states, and the causal consequences of those states—perhaps too much to attribute to someone so extremely young. A third, less potent alternative might be to say that certain contingency and timing relations attract an infant's attention to the side of the entity facing the infant and that, when that side turns, the turning of the facing part of the entity triggers in the infant a routine to look in the direction that is 90 degrees to the face of the object. In short, there might be a rich set of perceptual motor and attentional relationships set off by an object that responds contingently to one's voice, but that rich set of relationships may not be at the level of conscious beliefs.

It might seem implausible to think of the infant's responses as being outside the realm of beliefs, but consider what seem to be contingent non-conscious behaviours in other species. A sheep dog, for example, will actively attend to other animals (such as sheep) that act in a highly specific way contingent to the dog's behaviours. The dog then responds to these animals' behaviours by engaging itself in a set of herding behaviours. Many of the

dog's herding behaviours make the dog appear as though it is anticipating, in a very complex manner, where the other animals want to go. Still, we are much more inclined to see the dog's mental states as an intricate mix of perceptual, motor, attentional, and spatial relations than to see them at the level of explicit beliefs. That is, although complex herding behavior emerges, we are reluctant to grant the dog herding "beliefs" or concepts about the sheep it herds. Likewise with infants, the third alternative suggests that infants use a combination of various cues and relations, which include but are not exclusive to perceptual input, to react to stimuli in a seemingly belief-oriented way. Again, it is not necessarily the case that they must possess or use a richly structured set of beliefs about social contingencies.

In short, it seems plausible that rich sets of cognitive interconnections can lead to elaborate expectations about how certain objects will behave, given some initial information and with perhaps little or no prior relevant learning. Such a possibility would conflict with most, if not all, forms of empiricism. However, there is still enormous variety in the possible nature of these expectations, ranging from sets of explicit beliefs to sets of perceptual motor responses. The enlightened empiricist view of perceptual shunting to an all purpose learning circuit differs conceptually and importantly from this view. How might the two views be shown to be different experimentally? To address this issue, we must first consider in more depth what non-perceptual knowledge of categories must look like.

HIGH BUT SPARSE: RETHINKING WHAT IT MEANS TO HAVE HIGH-LEVEL CONCEPTUAL KNOWLEDGE

We have suggested that category knowledge can arise from psychological processes at many levels, ranging from sensory perception to explicit beliefs of the sort found in a detailed theory. In this framework, one might claim that there is a region of neural tissue that contains a theory of the behaviour of physical objects or a theory of biology and is just waiting to be filled with real-world examples. However, such characterisations of the theory-laden aspect of categorisation could be severely misleading. It is now generally acknowledged that much of human categorisation seems to make sense only in terms of explanatory knowledge that the categoriser has (Murphy & Medin, 1985). Consider the well-known example of a category that includes children, money, photograph albums, and pets. This category makes sense only if you know that it represents "things to take out of one's house in case of a fire" (Barsalou, 1983). Furthermore, people readily reject high correlations that make no theoretical sense and will inflate or even create correlations that fit with theoretical relations (Chapman & Chapman, 1969). People routinely weigh features and frequencies in ways that follow from reasonable causal interpretations of what is going on in a domain. For

instance, imagine that you were told that most of the athletes who qualified for the Olympic swimming team had certain properties, whereas most of those who did not qualify did not have those properties. Suppose you were further told that the qualifying athletes had broader shoulders, more ear piercings, diets higher in a certain protein, more cars with even numbers in their license plates, and lower resting heart rates than the non-qualifying athletes. No one would pay much attention to some of these properties, because they cannot fit into a coherent theory of what might help athletic performance.

The importance of theory-like relations to categorisation does not necessarily mean, however, that we have comprehensive, detailed theories of why aspects of the world are the way they are. Ask people how specific artefacts work as they do and you will usually find glaring holes in their knowledge, even when they might have previously expressed great confidence that they could answer the question with a high level of accuracy and detail (Rozenblit & Keil, 1999). Such holes, as well as inconsistencies and downright contradictions, are commonplace in folk beliefs about why things in the world around us are as they are (Wilson & Keil, 1998). Some have interpreted such limitations as clear indications that theories do not play any role in concepts at all (Fodor, 1998). Indeed, if our naive "theories" are to be understood as detailed, coherent theories either of the explicit or intuitive sort, then we would not be able to say that category knowledge arises from high level cognition. This would seem to be especially true of children, who have even less systematic knowledge than adults. Indeed, it might be adaptive to be able to reason effectively, and to categorise accurately, with such skeletal knowledge. It is not likely that we would always have a complete data set in front of us from which to categorise correctly, or unlimited time to process all the information. In real life, we have limited time to link the parts that we do know about and, from this, make inferences about the missing details. To make an analogy, it is like being able to perceive a whole object in spite of the presence of occluders that chop-up smooth contours and surface textures. It would seem, then, as if category knowledge might have more of a perceptual basis after all.

There is an alternative, however. We can consider the possibility that lay people might have high-level, theory-like knowledge that is quite sparse and skeletal in nature (Wilson & Keil, 1998). A general example of high-level but sparse category knowledge might be having a causal schema of what sorts of patterns go best in a domain without knowing the exact details of how something in that domain works (for instance, knowing how feedback systems work, which is a common principle in applied physics, but not knowing how a digital thermostat regulates system temperature). Similarly, a lay person's explanatory knowledge about the category of living things might include knowing that they reproduce (but not knowing how they do it), knowing that

each distinct biological kind has its own unique path of origin (two turtle doves do not grow from hatchling to mature birds by two radically different morphological routes) without knowing the details of those paths of origin, and so on. The point here is that one can know a great deal about members of a category that is by any account high level and abstract, but which is still sparse in terms of not knowing the details. In considering how we acquire category knowledge or in what becomes impaired and spared in neuropsychology cases, therefore, one must allow for this kind of theory-based knowledge without expecting fully worked-out mental models of some aspect of the world.

DISTINGUISHING THE MODELS

We have suggested that the organisation of our knowledge into concepts, including neural instantiations, might arise through specialisations for information at many different levels, ranging from the sensory and psychophysical to the theory-laden and causally interpreted. However, this suggestion is interesting from a developmental standpoint only if there are indeed ways to distinguish these levels of specialisation empirically. We think that there are, but that a substantial array of converging methods will be necessary to make sense of the issues that arise. To illustrate, we will first consider these issues framed as much more specific questions before we return to the broader question of how to differentiate the two accounts. Suppose, for example, that an individual suffered a stroke and has difficulty naming, recognising, and defining living things while keeping his ability to recognise artefacts relatively intact. A number of such cases have been reported in the literature (Humphreys & Forde, *in press*; Sartori & Job, 1988; Warrington & Shallice, 1984). There has been substantial debate with regard to the basis for such category-specific deficits, often revolving around the question of whether the deficit is that of being able to access such distinctions as functional versus perceptual features. By some accounts, functional features play a more important role for artefacts relative to perceptual features, so an impairment in access to perceptual features could cause a relative impairment in the ability to identify and possibly define living kinds (Farah & McClelland, 1991).

Such dichotomies, however, are inadequate to explain the deficits of all the patients in the literature, and more complex models are needed (Caramazza, 1998; Carmazza & Shelton, 1998; Humphreys & Forde, 2001; Shelton & Caramazza, 1999). In terms of the continuum of domain specificity we have described here, one can envision deficits at levels ranging from problems with certain kinds of visual features to problems in thinking about entities in teleological terms and, indeed, several patterns of neuropsychological data seem to require higher-level broad conceptual deficits that could arise from "a categorical structure for evolutionarily important categories of knowledge"

(Shelton, Fouch, & Carmazza, 1998, p. 339). In addition, various interactions between different kinds of information might be impaired. Indeed, it appears that many of these factors might be at work, and that theories will need to address several of them to be able to account for the full range of clinical cases (Humphreys & Forde, 2001). There is still, however, something of a bias in the literature towards explaining the effects in terms of deficits in feature types, such as perceptual and functional features, and a neglect of possible deficits in what we might call modes of construal—a kind of cognitive system for organising, processing, and interpreting information pertaining to a specific domain. Modes of construal are ways of interpreting or understanding information in a specific domain but also have more of a framework nature than a fully worked-out theory. Thus, a biological mode of construal might involve teleological reasoning, a search for essences and their links to surface phenomena and several other biases concerning the kinds of causal patternings in a domain (see Keil [1994] for a more in-depth look at the idea of modes of construal itself). Certainly, by one interpretation of the autism literature, deficits in such modes might be one factor contributing to a selective theory of mind impairment.

Indeed, it is not at all impossible that deficits might be partially due to damage in such higher-level conceptual systems. Imagine, for instance, that adults have a specialised neural system for thinking about essences. This "essentialist system" might have a complex structure that instigates a continuous search for deeper and deeper causes of surface phenomena. Imagine further that, for our concepts of living kinds, virtually all features of such kinds are linked in some way, perhaps through other features, to the essence of that concept (e.g. DNA). Thus, when our hypothetical neural "essentialist system" for living kinds is defective, the features might be less tightly associated with one another than they would be normally, and are therefore less useful for identifying instances of living things.

It is well known that explanatory schemata can heavily influence the subjective weightings of features (Murphy & Allopena, 1994), so it is not implausible that a missing essentialist bias might cause very different weightings of features for living kinds and result in lowered performance on a wide range of tasks applied to that domain. Furthermore, it might be that an essence bias would be more strongly connected to some kinds of features than to others. Perhaps the essence bias is triggered by salient perceptual features, which then motivate a search for underlying causes and hidden features. In effect, it is conceivable that a problem with such an essentialist bias might cause many of the deficits seen in the neuropsychological literature. Such an account is completely speculative at this time, but it makes a useful point. Neuropsychological data alone might be hard pressed to tease apart quite dramatically different alternatives as to the level of cognitive involvement. Greater insight can be gained from combining lesion studies with

imaging studies, and more still will be learned from transcranial magnetic stimulation (TMS) temporary "lesions", but even all of these collectively might have great difficulty distinguishing the levels at which the effects are occurring.

Thus, we must consider addressing the question from several other perspectives as well: chronometric, developmental, crosscultural, comparative across species, and in the normal range of individual differences. When these are combined with data on neuropsychological deficits, the relative importance of the different levels of information in everyday use of categories will become more apparent. Ultimately, then, the goal is not just to understand category-specific deficits in their own right but to understand how such deficits converge with other assessments of category knowledge. In this way, we can better understand how our knowledge of categories originates, functions, and is structured in its mature state. For complex reasons, it might be that lesions result in a much more refined differentiation of perceptual versus functional features than of different essentialist biases or teleological modes of construal. However, until converging evidence from a variety of methodologies is considered, it is risky to assume that perceptual and functional features represent the core basis for differences in knowledge across categories. A case in point, to return to an earlier example, is Ahn's (1998) demonstration that people rely more fundamentally on causal theories than on perceptual versus functional features to identify artifacts and natural kinds.

But, one might argue, consider another way in which perceptual versus functional features might distinguish the two kinds. Perhaps the ratio of functional features to perceptual ones is higher for artefacts than for living kinds (see Humphreys & Forde [2001] for a related discussion). Some patterns of brain damage could then differentially damage access to one of these feature types and thereby produce a deficit biased towards one category over another. Again, even if all of this were the case, even tentative conclusions about how categories are mentally represented should be drawn with great caution. To illustrate the problem, imagine a more extreme example. Presumably, a blind person should have far less access to perceptual features than a sighted individual, even if we allow for some compensation via increased sensitivity to auditory and tactile features. Thus, a blind individual's knowledge of living kind and artefact categories might be expected to be much more similar to each other, relative to a sighted individual, in terms of the relative ratios of perceptual and functional features. If this were the key representational difference between the two categories, one might expect, for instance, more conversational impasses in conversations with blind people about living kinds. However, no such conversational confusions have been reported. Moreover, lesions in regions that cause a deficit in thought about living things for sighted individuals would not be expected to have a comparable effect for blind people. We do not know of any specific

cases of this nature, but suspect that no such differences would be present following lesions in blind and sighted people. Thus, simply shifting the discussion to possible interesting scenarios presented by special populations illustrates more clearly the limitations of any one perspective and provides a basis for showing how different theoretical approaches make different predictions.

Indeed, focusing on functional and perceptual features as the critical difference between how the concepts of the two kinds of categories are represented seems less effective than considering a much wider range of perspectives. A look at the developmental literature reveals that even distinguishing perceptual from functional features is a far more tricky affair than it might first seem. Classic claims that children proceed from organising their worlds primarily in terms of perceptual features and only later in terms of functional features have proven to be difficult to support empirically (Keil et al., 1998). Young infants are capable of picking up on some functional features of objects at extremely early ages, such as graspability. Furthermore, the Gibsonian idea of affordances—properties of objects that afford actions—has blurred the perceptual/functional feature distinction almost completely (Adolph, Eppler, & Gibson, 1993; Gibson et al., 1987).

Thus, we have argued here for an approach in which we assume, by default, that all levels of information that could distinguish members of categories are used to make sense of the world, and that no one kind of feature is necessarily privileged, whether in terms of processing speed, neural instantiation, or development. Indeed, just as the classical idea of a perceptual to functional shift in development has foundered in recent years, so has the idea that perceptual features alone must be the first features to affect information processing. Of course, for novel objects out of context, perceptual features must be processed first, but for most things we perceive in the world, prior knowledge at all levels plays a role in constraining what information we pick up. Consider the phenomenon of inattentional blindness (Most et al., 2000; Simons & Levin, 1998). Depending on the task at hand, observers clearly do not see certain objects and/or events, even when they are directly in the centre of the visual field. Higher-level, theory-based expectations about what is being observed can cause "blindness" to that which is not expected. Similarly, in learning to categorise objects, expectations about plausible causal relations among properties will lead observers to more rapidly identify instances with causally plausible properties than those with properties that are less plausible but occur more frequently in training (Murphy, 2000).

When categorisation is viewed from the perspective of just one approach, whether it be category-specific brain damage, developmental change in categorisation, categorisation across species, or speed of access, a single level of analysis (often different depending on the particular approach) might appear to predominate. Only when these various perspectives are taken together can

we address the need to synthesise information at all possible levels. Moreover, it might also be of critical importance to consider interactions between these levels. In general, as we have pointed out, there seems to be a general tendency to model the representations subserving categorisation in terms of feature sets and their distributions (often with a bias towards perceptual features). Instead, interactions between features must be considered, especially those that capture causal and temporal relations. Additionally, it is important to note that there is more at work here than simply the notion that every possible bit of relevant information is important to our mental representations of categories. Rather, the argument is that an awareness of the multiple levels and their interactions should motivate studies aimed at unveiling a clearer assessment of what is central in learning, development, and mature functioning.

As a final example of how multiple research perspectives could be combined to gain a fuller view of multilevel categorisation, consider again the nativist-empiricist debate. How might one contrast the perceptual shunt "enlightened empiricist" accounts explaining the origins of our knowledge about living things from the more nativist accounts? The empiricist model would predict that infants who are exposed to very different informational patterns should have more radically different high-level cognitive systems as adults. Thus, one might expect blind and sighted individuals to have markedly different high-level cognitive organisations about living and artefact kinds. A more nativist view that sees rich prior organisation in dedicated neural circuits, even if it is below the level of specific beliefs, would see less variation across individuals with different experiences, assuming that either of these different experiences (i.e. blind and sighted) might be adequate to fill out the organisation in the circuits. Thus, studies in blind and sighted individuals aimed at investigating these hypotheses would be both viable and informative.

Another technique might be to look at normal individual differences, an approach rarely used to ask questions about the organisation of cognition. From the vast literature on intelligence, we know that there are individual differences in subcomponents of cognition such as spatial ability, verbal ability, and processing speed. Analogously, it seems plausible that the different levels of information that could inform categorisation would also show individual differences. As an example, take again the case of autism. There may be a continuum from autistic individuals to Asperger's to socially awkward people to those who are remarkably socially adroit (indeed, some have argued, not in jest, that men generally resemble autistic individuals more so than women do). It is possible, then, that there might be a distinct mental faculty for reasoning about social beings that varies across individuals. The same possibility exists for the ability to handle information at each of the levels that are relevant to categorisation. Some individuals might be better at coding functional features, others at seeing colour distributions,

others at encoding action-at-a-distance relations, and still others at making teleological inferences. Such an analysis, especially in conjunction with developmental ones, would help discriminate enlightened empiricist models from more nativist ones.

Recently, the values of an individual differences approach have been illustrated in a research programme examining the degree to which lexical versus syntactic development is associated with genetic variance. If identical (monozygotic) and fraternal (dizygotic) twins are compared in the developmental trajectories for their lexicons and syntactic structures, only the syntactic structures show a stronger correlation among identical twins than fraternal ones, suggesting a more direct role for domain-specific biological specialisations for syntax (Ganger, Pinker, Baker, & Chawla, 1999). This same kind of approach could be extended to many other areas of cognition as well.

One final approach in our multiperspective framework might be to examine comparative work across species. Increasingly, we see evidence of other species' sensitivity to real-world covariation between timing relations and specific domains. The development of taste aversion is the classic example, in which animals such as rats link their feeling of nausea with the taste of a food ingested hours earlier and not with a visual event occurring just prior to the nausea's onset (Garcia & Koelling, 1966; Rozin & Kalat, 1971). More recently, it has been shown that relatively unsophisticated primates, such as cotton top tamarins, assume that colour is more central to similarity of novel foods than it is to similarity of novel artefacts (Santos, Hauser, & Spelke, 2001). Thus, it is plausible that this sort of work could reveal that there are, even in species presumably less sophisticated than humans, the sorts of top-down, theory-influenced expectations about the kinds of correlations, contingencies, and features that are most relevant to a particular domain. Indeed, we have just suggested a variety of research approaches that together might provide insight on the question of whether the nativist and enlightened empiricist approaches are, in fact, distinguishable.

CONCLUSIONS

We have argued that categorisation might rely on information that is processed at many different levels of perception and cognition, and that discussion of the representational basis for categorisation to date has tended to focus solely on relatively low-level perceptual features. Recently, there has been a movement to look more at interactions between different levels of processing (Humphreys & Forde, *in press*). However, we see many more alternatives when the full range of possibilities is considered. There is an implicit bias in much of the developmental literature to assume that the perceptual is developmentally more basic than the conceptual, and thus more immediately and easily processed. We have, however, found little support for

such an assumption, and suggest that such a bias has led to a neglect of the various ways in which cognition about information relevant to category differences might be central to category-based knowledge. We recommend that an integrated perspective that links neuropsychology with several other approaches will bring more clarity to how we might use these different levels of information and how we might distinguish them empirically.

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