Conceptions of objects across categories:
Childhood patterns resemble those of adults.

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Studies of category-specific disorders have suggested that categories of living and non-living things vary in the properties that are most salient to recognition. Studies of the object features generated by normal adults have also revealed different patterns of responses to different categories. These adult patterns are likely to originate in childhood, but there are few reports of children's verbal conceptions of objects and none at present of objects from different categories. This paper investigates the development of object conceptions, in large group of children, aged 3years 7months to 11years 6 months, in response to 'What is a - ?" questions directed to seventy-two objects, selected from two categories of Living Things (animals and fruit/vegetables) and two categories of Artefacts (implements and vehicles). Proportions of perceptual-to-functional features provided by the children to living and non-living things varied with the range of features defined as functions, just as studies of adults have found. Apart from the distribution of superordinate responses, which were significantly more salient to living than to non-living categories, no other property separated the two categories. Only the category of implements could be distinguished from the other categories on the basis of the features generated. It is argued that the perceptual-functional of theory of category-specific disorders receives little support from this study, but that in general the distribution of features generated by young children is similar that produced by normal adults.

Numerous studies of adults with semantic memory impairments have reported difficulties with naming and defining objects belonging to particular categories of objects. Although it is possible that many of these cases arise as artefacts from the use of uncontrolled materials (Stuart, Parkin and Hunkin, 1992; Funnell and Sheridan, 1992; Gaffan and Heywood, 1993), the attempt to account for these disorders has stimulated an important debate about the mental representations underlying different object categories.

The most commonly reported category-specific impairments affect the naming and recognition of objects belonging to categories of living things, such as animals and fruits and vegetables. To account for this bias, it has been suggested that knowledge of the perceptual features of objects is particularly important for the recognition of living things - and also for some artefacts, such as musical instruments and buildings - so that when perceptual knowledge is impaired, these categories will be most affected. Sometimes, however, objects belonging mainly to nonliving categories, such as tools, are most impaired, and in these cases, functional information is thought to be particularly salient, so that, when functional knowledge is damaged, the recognition of small manipulable objects (but not larger objects such as vehicles and buildings) will be impaired (Warrington and Shallice 1984;Warrington and McCarthy, 1987).

Underlying the perceptual-functional theory of category specific impairments is the assumption that perceptual and functional knowledge are represented in such a way that each may be damaged more or less independently of the other. In line with this assumption, Miller and Johnson Laird (1976), Johnson Laird (1983) and Jackendoff (1987) distinguish between perceptual and conceptual representations of objects. They suggest that knowledge of the shape of objects is stored in perceptual paradigms that are involved in the creation of mental models of the three-dimensional world. Perceptual paradigms can be used to test a percept, or to describe an object verbally, while mental models can be used to compute images that represent the perceptible features of real world objects, indicating an interactive relationship between mental representations of perceptual and conceptual properties. In contrast to perceptual features, functional features are considered to be conceptual (Miller and Johnson Laird, 1976; Jackendoff, 1987) and are particularly critical aspects of most artefacts and more basic than object form (Miller and Johnson-Laird, 1976). Function has been proposed to determine the nature of the perceptual features of artefacts (Miller and Johnson Laird, 1976; Tyler, Moss, Durrant-Peatfield and Levy, 2000; Borgo and Shallice, 2001), and, as Miller and Johnson Laird (1976) and Johnson Laird (1983) have suggested, it is the use to which artefacts can be put that appears to distinguish them from living things.

Empirical evidence has supported these theoretical distinctions to some extent. A study that defined function narrowly, as 'what an object if used for', found that perceptual properties dominated dictionary definitions of living things by a ratio of 7 perceptual to 1 functional property, while a ratio of 3 perceptual to 2 functional properties for artefacts reflected a closer balance between the two (Farah and McClelland, 1991). Similar ratios of perceptual to functional features were found when normal adults were asked to generate features to living and nonliving things (McRae, de Sa and Seidenberg, 1997). Moreover, when computer simulations of a model based upon these ratios of perceptual to functional features were carried out, damage to perceptual features produced impairments to living things, while damage to functional features produced impairments to non-living things, consistent with the perceptual/functional hypothesis (Farah and McClelland, 1991).

However, further studies have shown that the dominance of perceptual features to the representations of living things depends upon the range of features included in the ‘functional’ category. When dictionary definitions of function were broadened to include all non-sensory properties, the relative dominance of perceptual knowledge in the representations of living things virtually disappeared (Caramazza and Shelton, 1998). When actions and activities were included, as well as object use, normal adults generated more perceptual than functional features to both living and nonliving things (Garrard, Lambon Ralph, Hodges and Patterson, 2001); and, when associative information was combined with function, the proportion of sensory to functional features was reduced particularly to living things, because living things generated more encyclopaedic properties. Using three different definitions of function, ranging from a narrow view (what it is used for) to the widest view that included all non-sensory features, McRae and Cree (2002) concluded that only the narrowest definition, which produced ratios of 6.4:1 sensory to function features for living things, and 2.2:1 features for nonliving things, distinguished between the categories.

Garrard et al (2001) used cluster analysis to determine category membership on the basis of the features generated to a mixed set of objects, and found three broad domains of objects: fruit, animate beings and artefacts. These semantic categories were argued to ‘emerge’ from the overlapping patterns of object features shared by the members in the set, as noted earlier by Rosch and Mervis (1975). A similar study, that described the properties generated to selected categories, found that creatures were characterised by many perceptual properties (such as colour and shape), many activities, and few functions (defined as the object’s use); fruit and vegetables were characterised by many perceptual features and some functional features (eg people cook them); and a collection of non-living things were characterised by many functions but few perceptual features (McRae and Cree 2002; Cree and McRea, 2003). These studies suggest that detailed analyses of the range of properties generated to a selection of different categories may reveal more information about the salience of particular properties than do broad comparisons between categories of living and non-living things.

The question that concerns this paper is whether or not the various patterns of features generated across categories, reported by Garrard et al (2001) and McRae and Cree (2002), have their origins in childhood. Computational modelling of development has suggested that early experience shapes the developing system with long lasting effects (Plaut and Shallice, 1993; Ellis and Lambon Ralph, 2001). In addition, differences in the age-of-acquisition of object names have been found to influence response time and accuracy in visual object naming tasks (eg Carroll and White, 1973; Gilhooly and Gilhooly, 1979; Brown and Watson, 1987; Morrison, Ellis and Quinlan, 1992), and to affect response time in some conceptual studies in adults (Van Loon-Vervoon, 1989; Brysbaert, Van Wijnendaele and De Deyne, 2000; Ghyselinck, 2002), although not others (Morrison, Ellis and Quinlan, 1992). Where age-of -acquisition effects occur, it suggests that representations laid down in childhood are likely to be involved, leading to the prediction that category-specific feature patterns similar to those observed in adults will be evident in children's data.

Studies of children's conceptual knowledge of objects have not so far reported comparisons across objects belonging to different categories, but a handful of studies have investigated children's knowledge of object properties. Based upon evidence from responses to 'What is a - ?' questions, McGregor, Friedman, Reilly and Newman (2002) found that the core concepts of objects held by children aged between 4y2m to

6y6m contained both functional and perceptual properties. Functional properties were defined broadly as ‘the purpose of the item, the people or instruments that act on the item, the way it is acted on, or the outcome of the item’s actions’, and perceptual properties as ‘physical properties, including colour, shape, smell, feel, composition, life cycle, and movement’, and the authors argued that only when object concepts contain knowledge of both perceptual and functional properties could objects be accurately identified by name.

However, in other studies, functional responses (defined as ‘what an object is for’) have been reported to dominate the responses made by children aged between 4y5m and 7y5m to the definitional questions contained in the WPPSI and WISC-R (Litowitz (1977); and to responses across four age groups of children (5y2m, 7y4m, 9y4m and11y6m) when function was defined as ‘an object’s use or an action it could perform’ (Wehren, De Lisi, and Arnold (1981). In the latter study, the proportion of functional responses decreased as responses containing combinations of response types increased with age; but purely perceptual responses (referred to as ‘concrete’ concepts) were consistently low in number across the age groups. This finding might reflect the dominance of artefacts in the set, since 32% of the perceptual responses produced were elicited by one item ‘tree’: the only living thing presented.

Linguistically, categories are distinguished by the use of superordinate terms. McRae and Cree (2002) found that adults are more likely to generate a superordinate label in response to animal names than to any other category except fruit and vegetables. Similarly, adults with semantic memory disorders are more likely to give superordinate responses to living things than to artefacts in naming and definition tasks (Funnell and de Mornay Davies, 1996; Moss, Tyler, Durrant Peatfield and Bunn 1998). Rosch, Mervis, Gray, Johnson and Boyes-Braem (1976) observed that objects belonging to biological categories share more features at the superordinate level, and therefore form tighter categories than other groups of objects. If these categories develop earlier, this might be reflected in the earlier use of the related superordinate terms. Rosch et al (1976) found that although children of 5 years 7months could sort both animals and vehicles on the basis of category, and could provide the superordinate term for the animals, fewer than 20% of vehicles were described by a superordinate term, providing some support for the view that some objects form categories more readily than others and that these differences can be observed in the response patterns established during early childhood.

There is general agreement in the children's literature that the 'best' definitions contain a superordinate term and some specific information (Litowitz, 1977; Benelli, Arcuri and Marchesini;1987; Johnson and Anglin, 1995; Kurland and Snow, 1997). Watson (1985) found that the question 'What kind of thing is a …?' elicited more superordinate terms than a non-specific probe question. However, children's definitions, particularly at young ages, often fail to include a known superordinate (Watson,1995; Snow,1990; Johnson and Anglin,1995). The use of superordinate terms by children has been found to increase with age. This may occur for a variety of reasons: because older children have greater knowledge of words; because they have better organised concepts; because they are more aware of the conventional use of the superordinate term in definitions; or because they benefit from an academic culture (Skwarchuk and Anglin,1997; Kurland and Snow, 1997; Snow, 1990).

Children younger than ten years are argued to find it difficult to cope with the cognitive demands of a formal definition requiring the combination of a category label and some specific information (McGhee Bidlack (1991), and even ten year old children produce such definitions for only 70% of object names presented (Kurland and Snow (1997). As children grow older, explicit superordinate terms (eg tool) begin to replace broad superordinate terms such as ‘thing’ and ‘something’ (McGhee Bidlack, 1991; Skwarchuk and Anglin, 1997). Interestingly, definitions given by ten-year-old children were not found to differ significantly from those of adults (Benelli, Arcuri and Marchesini, 1988; Kurland and Snow, 1997). However, as mentioned above, there is evidence to suggest that the use of superordinate terms by children may vary across category (Rosch et al, 1976): a finding that, if supported further, would undermine the view that the use of superordinate terms depends entirely upon developmental level.

This study reports an investigation into the different types of knowledge provided by a large group of primary school children, aged between 3years 7 months and 11 years 6 months, in response to ‘What is a-?’ questions. Such questions ensure that the responses given by the children are those that occur naturally to them and presumably contain the most salient information. Objects were selected from four categories – animals, fruit/vegetables, implements, and vehicles - that differ in animacy, visual similarity, and manipulability. Living things are considered to be more perceptually similar to each other (Humphreys, Riddoch and Quinlan, 1988; Gaffan and Heywood, 1993), and to share more attributes in common at the superordinate level than do non-living things (Rosch et al, 1976). Implements are considered to be more manipulable than vehicles and animals (McCarthy and Warrington, 1988), and the perceptual similarity of motor patterns has been found to serve as common attributes in the construction of categories at the basic level (Rosch et al (1976).

Predictions based upon theories of object representations suggest that perceptual information should dominate children's responses to living things (Warrington and Shallice, 1983; Farah and McClelland, 1991) and to non-manipulable artefacts such as vehicles (McCarthy and Warrington, 1988). In contrast, if functional knowledge is critical to the representations of artefacts (Miller and Johnson-Laird, 1976), these should dominate responses to manipulable objects in particular. Superordinate responses are expected to be more common to living things although the developmental literature suggests that the use of superordinate responses in general emerges with increasing age. Empirical evidence obtained from normal adults indicates that there may be contributions from further features, such as 'encyclopaedic information', and 'activities' to consider (Garrard et al, 2001; McRae and Cree, 2002) if the responses given by adults have their antecedents in childhood. Finally, according to Mandler (1997), young infants can form perceptual categories with no conceptual content. On this view, it might be expected that the features of objects that the youngest children in the sample produce should be mainly perceptual.

EXPERIMENT 1

Method

Participants

The study involved 288 children, aged between 3 years 7 months and 11 years 6 months. All the children spoke English as a first language and no one had an official statement of special needs. There were 36 children in any twelve-month age group and three boys and three girls in every two-month age band. The children were selected from eight state-maintained schools: one located in Inner London, five in

Outer London, and two in the Home Counties. The full age range was tested at all schools except the Inner London school where testing began at five years.

Materials

Eighteen objects, of varying difficulty, were selected for each of the four categories of animals, fruit/vegetables, implements and vehicles. Using measures of objective age-of-acquisition of naming (Morrison, Chappell and Ellis, 1997), and evidence of knowledge acquisition from a pilot study (reported in Funnell, Hughes and Woodcock, 2004), we selected for each category 3 objects with names or knowledge acquired before 3 years; 3 objects acquired after 11 years; and 3 objects acquired in each of the age ranges 3–5 years; 5-7 years; 7–9 years and 9–11 years. The seventy-two test items were ranked in approximate age-of-acquisition, and were ordered so that no more than two items from the same category appeared in succession.

Procedure

Children were seen individually on two or three separate occasions, in a quiet place at school. Each spoken object name was introduced as part of a general spoken question, *'What is a - ?'* and the child's response was noted. This question was followed by five probe questions (reported in Funnell et al, 2004) that were designed to elicit specific knowledge. A child was considered to have reached ceiling for a particular category when four successive items, or a total of six items from that category, failed to elicit any correct responses to the probe questions. No more items from that category were then given. Testing continued until the child reached ceiling, or the final item, in all four categories.

Results

a) Scoring

Children did not always respond to '*What is a - ?'* questions. However, even the youngest children 3y 7m – 4y 6m made sufficient responses (N = 705) to warrant analysis. The number of responses increased steadily with age, reaching a total of 2,076 responses in the oldest age group. Although the total number of responses varied across age, the mean percentage of responses in each category was virtually constant across age: animals 26.7 (sd 1.6); fruit/vegetables 25.7 (1.9); implements 24.4 (1.5); and vehicles 23.2 (1.3).

Children's responses were classified into five groups: superordinate, perceptual, factual, functional and action. A response was classed as a superordinate when applied appropriately as a category label. We accepted animal and creature for all types of animals, and mammal, marsupial, bird, and insect when appropriately applied. For fruit/vegetables we accepted plant, fruit, vegetables when appropriately applied, but we accepted any of these terms for tomato, aubergine, courgette (which are technically fruits) and rhubarb (which is technically a vegetable). Implement, tool, and machine were accepted as superordinate terms for implements; and for vehicles, we accepted transport, vehicle, machine, and boat (for water craft only).

We defined perceptual responses as named features that could be seen, heard, felt or tasted: for example, 'A cow says "moo"'; 'A giraffe's got a long neck'; A lemon is sour'. This is a 'tighter' definition of perceptual responses than that used by McGregor et al (2002), who included life cycle in their list of otherwise physical properties of objects, but one that conforms to adult studies that limit definitions of perceptual properties to those attributes that can be processed by a sensory modality, such as colour and shape (Caramazza and Shelton, 1998; Garrard et al, 2001; McCrae and Cree, 2002).

Factual responses referred to encyclopaedic information: e.g. ‘A koala lives in Australia’; information about an animal’s behaviour: e.g. ‘A beaver blocks water with sticks’; and information that could not be deduced from visual inspection of the object: e.g. ‘A submarine has missiles’. Garrard et al (2001) used a similar definition of encyclopaedic knowledge, which they describe as associative, giving as examples ‘A tiger is found in India’ and ‘A toaster is kept in the kitchen’.

We chose to define function narrowly, as the ‘the purpose of objects’ (eg ‘A spanner’s for undoing nuts’), because studies with adults have found that this feature distinguishs best between categories of living things and non-living things (Farah and McClelland, 1991; McRae and Cree, 2001). We treated action as a separate type of knowledge, defining it as ‘What is done to objects in the process of using them’, as, for example, the comment “You twist it around” that was given as a response to the word ‘spanner’. Some studies of adults (Garrod et al, 2001; Caramazza and Shelton, 1998)) have included action in the definition of function, as have studies of children (McGregor et al, 2002; Wehren, De Lisi, and Arnold, 1981), but we were concerned to explore the individual contribution that action might bring to implements compared with other categories (McCarthy and Warrington, 1988).

Responses that provided irrelevant information were not included in the analysis but, because our analysis was directed to collecting information about the types of responses that children gave, we included a few instances of plausible information e.g. ‘a penguin has a fur coat’, and information relating to close semantic neighbours e.g. ‘a microscope’s for looking at the stars’.

In this analysis, we were interested in the type of information volunteered and how this might change over age, in contrast to most adult studies that have calculated the total number of features produced of each type. For this reason we awarded a single information point to each type of feature (i.e. superordinate, perceptual, functional, factual or action) that was produced in a single response. However, a small number of children repeatedly produced groups of shared perceptual features such as 'Its got legs, it's got fur', to several animals. Also, a very small proportion of factual, functional and action responses included multiple examples of the same type. For example, the word 'spoon' elicited two pieces of functional information "It's for stirring and eating ice cream"; and the word 'corkscrew' elicited three actions "You drill it into wine bottle, you turn the handle, and you pull." In all these cases, the feature set was counted as a single information point. This method of analysis allows changes in the proportion of a particular response type over age, to be expressed as changes in the proportion of children producing that type of response.

b) Data analysis

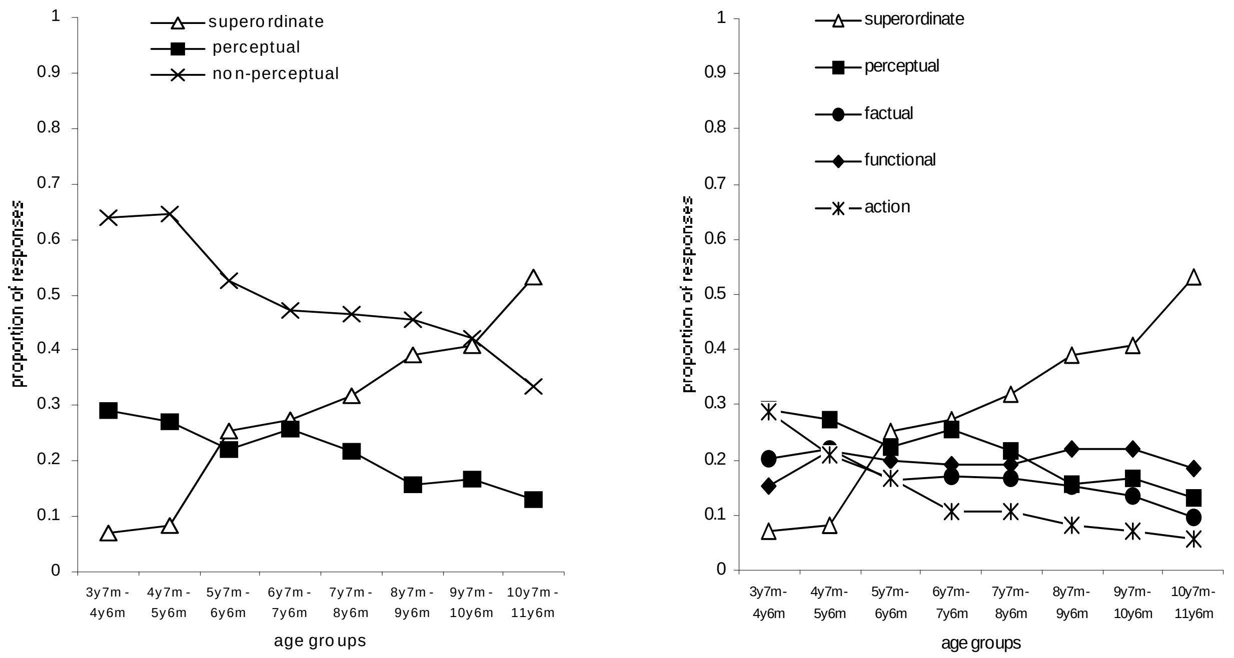
Children were treated as subjects in this analysis. First, we calculated the number of each child's information points for each of the five types of response to the objects in each category. We then calculated each response type as a proportion of the total information points given by the child to that category. These data formed the basis of each of the following four analyses.

Analysis of all object categories combined.

Our first analysis examined the proportions of response types made by children in each age group, collapsed across category. Figure 1a shows that the proportion of non-perceptual responses (that is, functional, factual and action responses combined) significantly outnumbered perceptual responses (repeated measures ANOVA: $F (1,280 = 352.6, p < 0.001)$: a difference that is apparent across the age range. Figure 1b presents the same data but with the different types of non-perceptual responses plotted separately. Using repeated measures ANOVA, we found a main effect of response type $F (4,277) = 42.84$, $p < 0.001$, in which pair-wise comparisons show that more children gave superordinate responses than any other type of response. Perceptual responses did not differ in proportion to functional responses, but both were more numerous than factual responses, which, in turn, were more numerous than actions (all differences $p < 0.001$).

There was also an interaction with age and response type ($F (28,1120) = 7.74$, $p < 0.001$). Action responses, which were prominent in the youngest children's responses, declined over age and were the least likely response after 6 years 6 months. In contrast, superordinate terms increased with age relative to other response types: these were the least likely response before the age of 5y7m but the most likely response in all following age groups. These initial results, which will be qualified later, support the view that superordinate responses are infrequent in children below five years of age, and increase slowly to reach a sub-optimal level (in this study less than 55%) of response types in older children of 10+ years.

FIGURE 1



Analysis across living and non-living things.

Our second analysis examined the proportions of response types given to non-living things and nonliving things. Figure 2a presents the proportion of responses to living things with all non-perceptual response types combined. A repeated measures ANOVA revealed a significant effect of response type (F (1.71,280) = 61.3, p < 0.001). Pair-wise comparisons showed that children produced significantly higher proportions of superordinate responses than non-perceptual responses, which significantly outnumbered perceptual responses (all comparisons p< 0.001). When overall numbers, rather than proportions of perceptual and non-perceptual responses were counted, non-perceptual features outnumbered perceptual features by a ratio of 4 to 3.

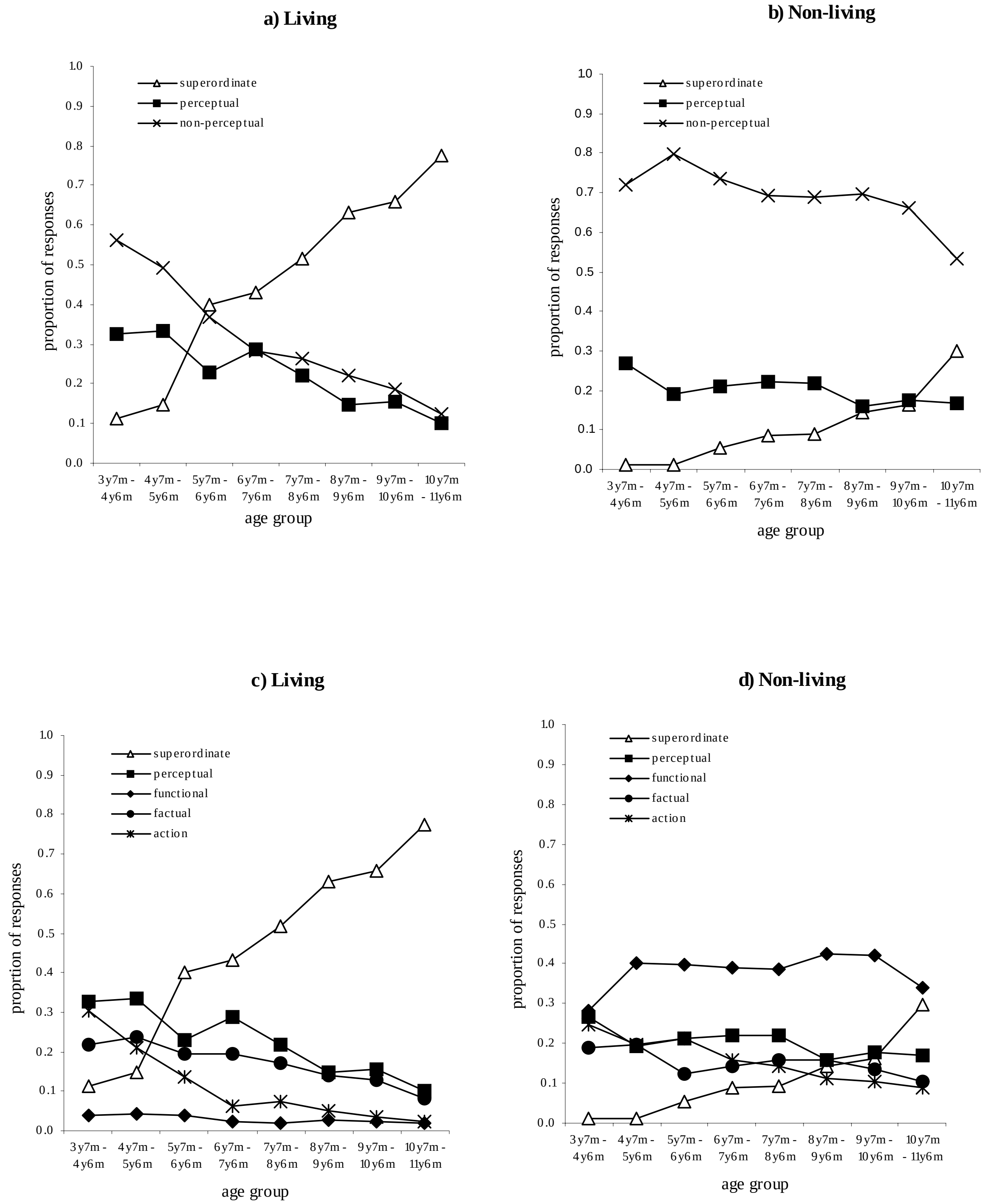
Figure 2b) presents the proportions of all types of responses given to living things. Using repeated measures ANOVA, we again found a significant effect of response type F(2.01, 280) = 237.1, p<0.001). Pair-wise comparisons revealed significant differences (p < 0.001) between each response type in which the proportion of response type descended in the following order: superodinate > perceptual> factual > action > functional. As Figure 2b) shows, children of all ages produced more perceptual and fewer functional responses to living things than any other response type. When numbers of responses types were counted, perceptual responses outnumbered functional responses to living things by a ratio of 7 to 1.

Turning to non-living things, Figure 2c presents the proportion of superordinate, perceptual and non-perceptual responses combined. There was a significant effect of response type (repeated measures ANOVA (1.65,280) = 747.64, p < 0.001). Pair-wise comparisons revealed significant differences between all response types, in which the proportions of non-perceptual responses outnumbered those of perceptual responses, which in turn outnumbered superordinate responses. Counting the overall numbers of responses given, non-perceptual responses outnumbered perceptual responses to nonliving things by a ratio of 7 to2.

Figure 2d presents the proportions of non-perceptual responses given to non-living things differentiated according to type. Again, we found a significant effect of response type (F (21.8,280) = 7.52, p <0.001). Pair-wise comparisons revealed that overall proportions of superordinate responses were significantly lower than all other response types. Functional responses significantly outnumbered perceptual responses, and these significantly outnumbered factual responses, which did not differ from factual responses. As Figure 2d shows, proportions of functional responses exceeded perceptual and action responses in all but the youngest age group. Counting numbers rather than proportions of responses, functional responses outnumbered perceptual responses to non-living things by a ratio of 2 to 1.

In summary, this analysis has shown that perceptual properties dominate

FIGURE 2



responses to living things when compared with functional responses, but this domination disappears when functional responses are combined with other non-perceptual response types. In contrast, both functional and non-perceptual properties combined dominate the responses to non-living things.

Analysis by individual category

Our third analysis investigated the proportion of response types within each category made by children at different ages. The findings are presented in Figure 3. Separate related MANOVAs revealed a main effect of response type for each category (Animals $F(3,276) = 788.13$); Fruit/vegetables $F(4,275) = 1162.28$; Implements $F(4,275) = 381.76$; Vehicles $F(4,273) = 49.61$: all significant at $p < 0.001$. To control for the number of comparisons made in subsequent analyses, the results are considered to be significant if the F contrast exceeds the critical F at a probability of 0.05 or more. In all these comparisons, significance can be assumed to be at the $p = 0.001$ level unless otherwise stated.

For animals, superordinate responses significantly outnumbered all other response types ($t = -12.55$; $F_{cont.} = 157.5 > F_{crit.} = 16.26$), and the proportion increased markedly with age. Perceptual and factual responses significantly outnumbered functional responses ($t = 19.15$; $F_{cont.} = 366.7 > F_{crit.} = 13.82$), which failed to reach 10% in any age group. No action responses were made.

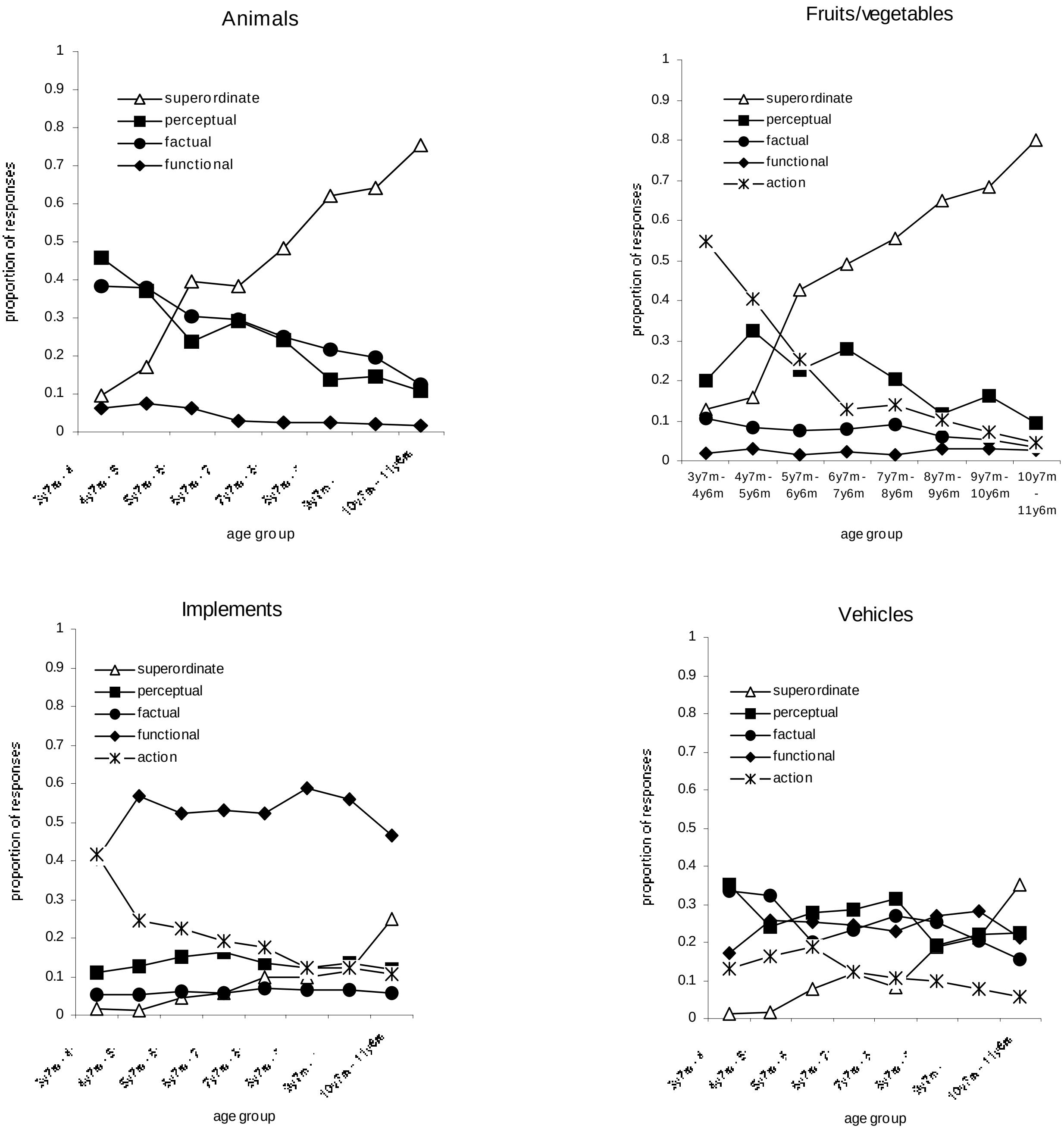
For fruit/vegetables, superordinate responses again significantly outnumbered all other responses ($t = 17.37$; $F_{cont.} = 301.7 > F_{crit.}$ 18.48) and increased markedly with age. Perceptual responses did not differ in proportion from action responses and there was no interaction with age. However, proportions of perceptual and action responses exceeded proportions of factual and functional responses ($t = 18.18$, Fcont.

= 330.5 > Fcrit. = 16.26), and there was a significant age by response type interaction (t = -10.38; Fcont. = 107.7 > Fcrit. = 44.7) reflecting decreases in proportions of perceptual and action responses with age. Factual and functional responses differed in proportion (t = 7.57; Fcont. = 57.3 > Fcrit. = 16.26), but there was no interaction with age.

For implements, the proportions of functional responses exceeded action responses in all but the youngest age group (t = 17.35; Fcont. = 301.02 > Fcrit. = 16.26), and exceeded all other response types. Action responses also exceeded perceptual responses (t = -4.1; Fcont. = 16.81 > Fcrit. = 16.26). There was a significant age by response type interaction between superordinate and other response types (t = -8.12; Fcont. = 65.93 > Fcrit. 59.64). Finally, for vehicles, action responses were significantly inferior to perceptual/factual/functional response types (t = 13.2; Fcont. = 173.7 > Fcrit. = 16.26), and there was a significant age by response type interaction between superordinate and other response types (t = -10.2; F cont. = 104.0 > Fcrit. = 59.6).

In summary, the profiles of response types differed for each category. Factual and perceptual responses characterised responses to animals from the earliest age, superordinate responses increased markedly with age, functional responses were consistently low across age, and action responses were never made. Action and perceptual responses were most marked for fruits and vegetables, and action responses were particularly marked at the youngest ages; superordinate responses increased markedly with age, and proportions of factual and functional responses were consistently low. Functional responses characterised implements across the age range, action responses were prominent in the youngest age groups, perceptual and factual responses were produced at low levels, and superordinate responses increased slowly with age. Finally, action responses were the least common response to vehicles; while proportions of perceptual, factual and functional responses did not differ, and superordinate responses increased slowly over age.

FIGURE 3



Analysis by response type

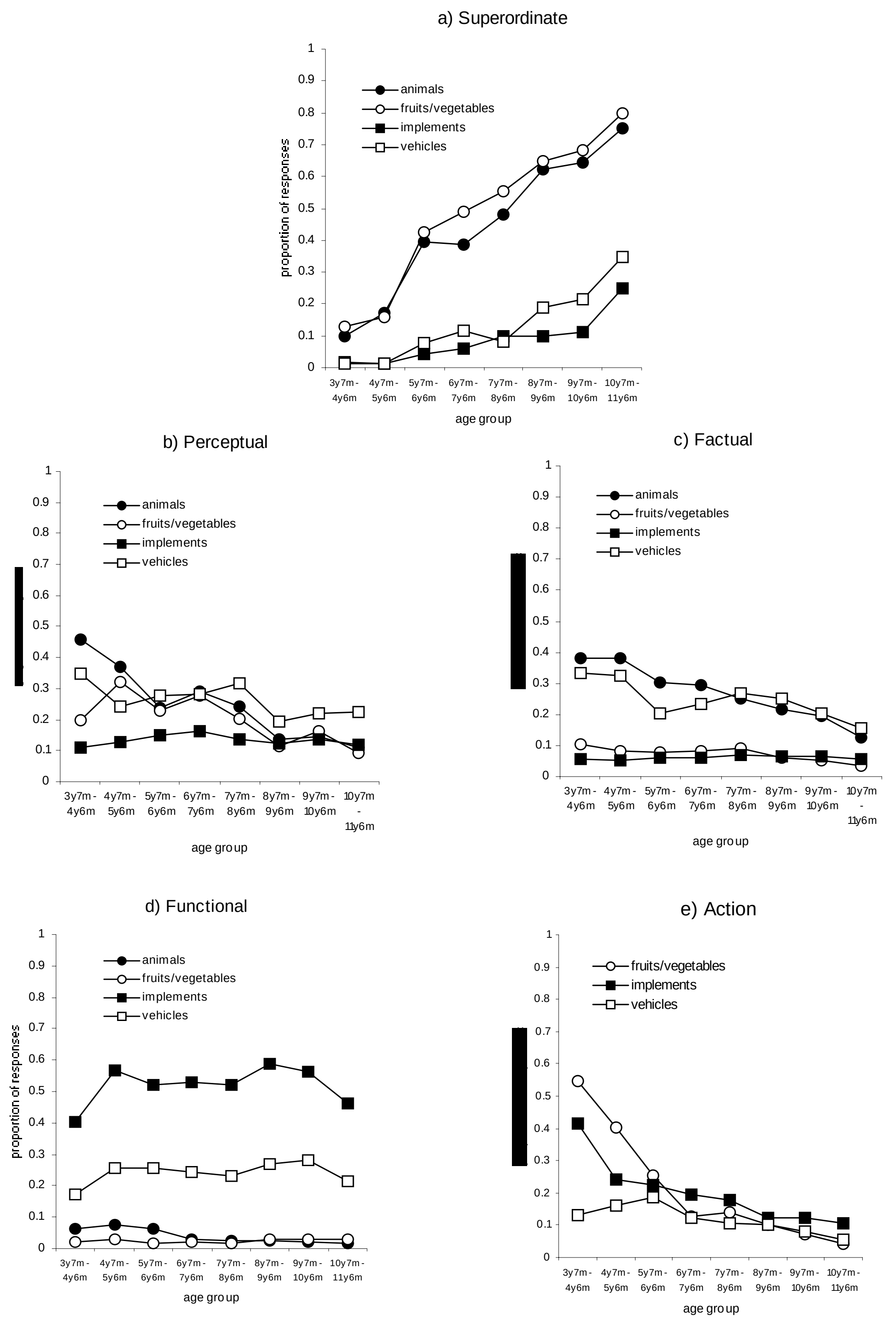
Our final analysis investigated each response type in turn, examining the relative proportions of each type of response produced in each category (see Figure 4). As before, differences between contrast F and critical F were used to establish significance that can be assumed to be at the $p = 0.001$ level unless otherwise stated. As Figure 4a shows, proportions of superordinate responses to animals and fruit/vegetables significantly outnumbered other categories of artefacts ($t = 27.16$; F cont. = 739.9 > Fcrit. = 16.26). Superordinate responses increased sharply from around 10% at the youngest age to over 75%, and produced a significant age by category interaction ($t = 10.0$; F cont. = 100.6 > Fcrit. = 44.7).

In both categories there was a noticeable spurt in the proportion of superordinate responses between 4y7m and 6y6m. Relatively few superordinate terms were produced for implements and vehicles, which increased slowly from close to zero at the youngest age to less than 40% by the end of the age range. Clearly, the marked superiority of superordinate responses, reported in the combined analysis (see Figure 1b), was supported in the main by the responses made to the living categories.

Examples of definitions comprising a superordinate term accompanied by a qualifying statement were evident from an early age. Three children in the youngest age group produced such definitions to animals (for example, “A big animal with a very long neck; it’s blacky yellow” in response to giraffe); and two children in this age group produced such definitions to fruits/vegetables (for example, “Fruit, you eat them” in response to the word ‘grapes’). Definitions of this type did not appear in response to vehicles and implements until a later age. Three children produced a definition for at least one vehicle at age 5y7m to 6y6m (for example, “A machine for soldiers, it shoots bombs” to the word ‘tank’) and three children aged 6y7m to 7y6m, defined at least one implement (for example, "A tool, its flat at the front. You try to get stuff off with it" to the word 'chisel'). Thus the children's use of a superordinate term, with or without a qualifying statement, varies with the nature of the category.

Analyses of the remaining response-types, using related MANOVA, showed

FIGURE 4



an effect of category (Perceptual $F(3,271) = 47.46$; Factual $F(3,271) = 166.86$; Functional $F(3,271) = 655.40$; Action $F(2,272) = 45.24$; all significant at $p < 0.001$), and each showed a different profile (see Figures 4b-e). Further analysis of each feature type revealed the following characteristics (Fcont exceeding Fcrit at the $p = 0.001$ level unless otherwise stated).

The perceptual responses, shown in Figure 4b, were significantly lower to implements than to all other categories ($t = 10.73$, Fcont. = 115.1 >Fcrit. = 16.26), and there was a significant age by category interaction ($t = -6.33$; Fcont. = 40.1 > Fcrit. = 37.59, $p = 0.01$). Equivalent proportions of perceptual responses were produced to animals and vehicles and both significantly outnumbered the perceptual responses produced to fruits/vegetables (animals: $t = 4.09$, Fcont. = 16.73 > Fcrit. = 16.26; vehicles: ($F = 4.28$, Fcont. = 18.32 > Fcrit = 16.26).

The factual responses made to animals and vehicles, shown in Figure 4c, significantly exceeded factual responses to fruit/vegetables and implements ($t = 22.4$; Fcont. = 501.8 > Fcrit. = 16.26). There was also a significant category by age interaction ($t = -6.6$; Fcont. = 43.16 > Fcrit. = 37.59, $p = 0.01$), in which responses to animals and vehicles declined over age relative to the other categories, but comparisons within these groupings were insignificant.

The functional responses to implements, shown in Figure 4d, significantly exceeded the functional responses to vehicles ($t = 22.89$; Fcont. = 524.0 > Fcrit. = 16.26), and functional responses to vehicles significantly exceeded functional responses to animals and fruits/vegetables ($t = -25.23$; Fcont. = 636.6 > Fcrit = 16.26). Finally, equivalent proportions of action responses (see Figure 3e) were produced to implements and fruits/vegetables and, in both cases, these proportions of action responses significantly exceeded the proportions of action responses made to vehicles (implements: t = 7.24; Fcont. = 52.4 > Fcrit. = 13.82; fruit/vegetables: t = 7.88; Fcont. = 62.1 > Fcrit. = 13.8). No action responses were produced to animals.

In summary, the use of a superordinate term distinguished between living and non-living things, as also did functional information. Functional information further separated implements from vehicles while perceptual knowledge distinguished implements from all other categories. Finally, factual information separated animals and vehicles from implements and fruit and vegetables, while action knowledge separated animals from all other categories.

Discussion:

This cross-sectional study of the development of children's responses to 'What is a - ?' questions has revealed bountiful data about the development of object knowledge in children aged from 3y 7m to 11 y 6m. Even the youngest children in the group were able to produce a variety of response types to different objects, and in sufficient numbers to warrant analysis. In total, the children produced equivalent numbers of perceptual to functional features, but higher proportions of perceptual to functional features were produced to living things than to nonliving things. In line with studies of adults that have used similarly narrow definitions of function (Farah and McClelland, 1991; McRae and Cree, 2002), the children produced greater numbers of perceptual than functional features to living things (in a ratio of 7 to 1), and roughly equivalent ratios of to non-living things; although, unlike the adult data, the children responses showed a slight advantage to functional knowledge (in a ratio of 1 perceptual to 2 functional responses). Thus, at this level of analysis, the children's data provide particularly strong support for the perceptual-functional hypothesis of category-specific disorders, first proposed by Warrington and Shallice (1984).

However, when functional features were combined with actions and factual knowledge, these greatly outnumbered the proportions of perceptual responses obtained for both non-living and for living things. Non-perceptual responses dominated both categories in ratios of 3 perceptual to 4 non-perceptual features to living things, and 7 non-perceptual to 2 perceptual to nonliving things. These findings support those of previous studies that have manipulated the relative proportions of perceptual to functional features by varying the breadth of definitions of object function (Caramazza and Shelton,1998; Garrard et al, 2001; McRae and Cree, 2002). Together, they show that although perceptual properties outnumber functional properties to living things, they are not the most salient property overall, in contrast to the predictions of the perceptual-functional hypothesis. At this level of analysis however, functional responses continue to appear to be the hallmark of non-living things.

In contrast to our findings, studies of children's definitions have typically reported a predominance of functional responses in object definitions (Litovitz, 1977; Wehren, De Lisa, and Arnold, 1981; McGregor et al, 2002). In part, this may reflect differences in the range of information deemed to be 'functional'. Our definition of function (defined as 'what an object is used for') was narrower than that of McGregor et al (2002) and Wehren et al (1981), although not of Litowitz (1977). In addition, different proportions of perceptual and functional responses may reflect differences in the balance of the categories represented in the stimuli. Artefacts have tended to dominate the stimuli in studies with children: for example, sixteen artefacts and four living things were presented by McGregor et al, (2002); 14 artefacts and 1 living thing were presented by Wehren et al (1981); and artefacts dominate the early definitional questions contained in the WIPPSI and WISC-R, used by Litovitz (1977). Thus it is perhaps not surprising that functional responses have been found to outnumber perceptual responses in these studies.

Like McRae and Cree (2002), we found that individual categories produced different profiles of perceptual and functional features in the children's data. Both studies found that animals and fruits and vegetables generated many perceptual features and few functions, and both McRae and Cree's 'collection of nonliving things' and our category of 'implements' produced many functions but fewer perceptual features. We found in addition, that animals were characterised by high proportions of factual and perceptual responses and an absence of action responses (defined as 'what is done to objects in the process of using them'). In contrast, fruits and vegetables were characterised by high levels of action and perceptual responses, and low proportions of factual responses. Action responses (such as 'you eat it' and 'you bite it') were particularly common to fruits and vegetables in very early childhood, but decreased markedly over age in proportion to other response types. The higher proportion of factual responses to animals than fruit/vegetables presumably reflects the fact that people in general possess more information about animals; while the lower proportion of action responses to animals than fruits/vegetables probably reflects the fact that relatively few animals have purposes for people: we considered that our sample included just four examples of such animals (cow, camel, donkey and llama).

Implements were characterised by outstandingly high proportions of functional responses. These proportions were consistent across age, and significantly outnumbered proportions of action responses, except in the youngest age group.

Actions also exceeded perceptual and factual responses, indicating the practical nature of implements. In contrast, vehicles were characterised by relatively low levels of functional responses (which did not differ in proportion from perceptual and factual responses) and even lower proportions of actions, which differed from all other response types. Surprisingly, even generic action responses, such as ‘you drive it’ to motor vehicles, generally did not occur.

As the data reported above suggest, it is difficult to find features that characterise either a particular category of object or a broader domain of living or non-living thing. Rather, as Garrard et al (2001) observed, it is the criss-crossing of feature types across members of a category that sets the category apart. Relatively low levels of perceptual responses distinguish implements from all other categories; superior proportions of factual properties distinguish animals (cf Garrard et al, 2001) and vehicles from fruit/vegetables and implements; while the absence of action responses distinguish animals from all other categories. Only object function differentiates significantly between living and non-living things; and even then significantly more functional features were produced to implements than to vehicles. Furthermore, only in the case of implements did the proportions of functional features significantly supersede other feature types. Thus, although function appears to characterise implements, there is little evidence from this study, that the remaining categories can be differentiated on the basis of particular features.

These data undermine the view that the classic distinction between living and non-living things, observed in cases of neuropsychological impairment, is based upon the loss or retention of particular types of features (Warrington and Shallice, 1984; Warrington and McCarthy, 1987). Perceptual knowledge does not dominate the responses made by children to living things, although it is the case that perceptual properties are the only feature on which both animals and fruit/vegetables scored highly. Neither does knowledge of function dominate responses to non-living things: only to implements was this property the most salient. However, two hypotheses put forward by McCarthy and Warrington (1988) to explain category-specific differences in performance across small and large nonliving things were upheld by this study. Significantly more action responses, and significantly fewer perceptual responses, were elicited to implements than to vehicles, and perceptual responses to vehicles were at least equivalent in number to those given to categories of living things.

Superordinate responses do however distinguished between categories of objects. While proportions of superordinate responses increased over age relative to other response types, these differed strikingly across living and nonliving things. Even among the youngest age groups, almost 20% of the children's responses to animals and to fruit and vegetables consisted of a superordinate term. Marked increases in the use of superordinates for both categories were observed between age groups 4y7m-5y6m and 5y7m to 6y6m, which may reflect the influence of schooling. Not until the children reached the age of 8y7m did the proportion of superordinate responses for vehicles reach the 20% level, and implements did not attain this level until the children reached the age of 11y7m.

The different use of superordinate terms to categories of living and nonliving things, found in the children's data, fits well with a number of other findings: that overlapping attributes define living (but not nonliving) things at the superordinate level (Rosch et al 1976); that normal adult are more likely to provide superordinate terms to living than non-living things (McRae and Cree, 2002); and that people with semantic disorders are more likely to respond with a superordinate term to living than non-living things (Funnell and De Mornay Davies, 1996; Tyler and Moss, 1997). The results of this study indicate that the different use of superordinate terms across categories have their origins in early childhood.

Studies of the development of superordinate responses in childhood have emphasised the relatively late emergence of these response types over age (Watson, 1995; Snow, 1990; Johnson and Anglin, 1995). However, our results show that the incidence of superordinate responses at any particular age depends upon how well a particular set of objects ‘afford’ a superordinante term (cf Garrard, Lambon Ralph, Hodges and Patterson, 2001). Categories of living things elicited superordinate responses from a very early age and were much more frequent than superordinate responses to either implements or vehicles. Thus, our prediction that categories of artefacts should produce superordinate responses based upon associations of shared motor patterns (cf Rosch et al, 1976) was not supported.

Nevertheless, a good number of superordinate responses were produced by older children to tools (ie hammer, chisel, saw and spanner), while very few were elicited by some other implements, (ie, binoculars, camera, grater, and microscope), indicating the presence of sub-groups within the category. Similarly, while water-craft in particular attracted a good number of superordinate responses in the vehicle category, others attracted virtually none. Thus categories of implements and vehicles appeared to contain a heterogeneous collection of objects, in contrast to biological categories that form more homogeneous groupings (cf Rosch et al, 1976). In consequence, when the incidence of superordinate responses is compared across categories of living and non-living things, it is unlikely that like is being compared with like.

Children below the age of ten years have been considered to be unlikely to produce the ‘best’ object definitions composed of a superordinate term and a specific qualifying statement (Litowitz, 1977; Benelli, Johnson and Anglin, 1995; Kurland and Snow, 1997), perhaps because young children find it difficult to focus on both the form and the content of definitions (McGhee Bidlack, 1991). In our study however, some young children aged between 3 years 7months and 4 years 6 months were able to produce such definitions to animals and fruit/vegetables, and some children aged 5y7m to 6y6m were able to do this for vehicles; only the older children aged 7y7m to 8y6m could produce these definitions to implements. Clearly some children can produce such definitions from an early age, and the likelihood of doing so appears to vary partly with mental capacity, as measured by differences in age, and also by the degree to which an object affords a category label.

In summary, our study has supported the expectation that adult conceptions of objects have their origins in childhood. Our results correspond well with adult studies, despite the different methods that have been used to elicit and analyse responses. Perceptual responses and functional responses can both be found in high proportions from the youngest age, indicating that children as young as 3 to 4 years can form categories containing conceptual information, although this is not thought to be the case in very early infancy (Mandler, 1987). Superordinate responses are most salient to the living categories and were made by some of the youngest children, questioning the view that the use of superordinate terms develops at a relatively late age. Perceptual responses are more salient than functional properties to animals, fruit/vegetables and vehicles, although they are not the most salient property overall. Functional responses are particularly salient to manipulable objects. Action responses are salient to manipulable objects and to fruit and vegetables in the youngest age groups, but are notably absent responses to animals. Factual responses are most numerous to animals and vehicles. Since information about function, action, and fact has been found to dissociate across categories, these properties must reflect different mental constructs. Classifications that group together these response types will therefore miss potentially important distinctions.

Finally, although perceptual knowledge is generally distinguished from conceptual knowledge in theories of object representation (Miller and Johnson-Laird, 1976; Johnson Laird, 1983; Jackendoff, 1987), the fact that the children's conceptualisations of objects included significant amounts of perceptual information supports the view that, whatever the underlying representation, 'knowing what an object looks like is part of knowing what an object is' (Jackendoff, 1987; McGregor et al, 2002).

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