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Continuity and Change in the Development of Category Structure: Insights from the Semantic Fluency Task

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Abstract

Children aged between 5 and 10 years old were tested on a semantic fluency (freelisting) task for two categories: animals and body parts. Additive tree analysis (Sattath & Tversky, 1977) was used to clusters items based upon both their proximity in the generated lists and their frequency of co-occurrence; the resulting trees together with production frequency data were compared across three age groups. For the animals category, this analysis revealed that although older children named proportionally more non-mammals, at all ages children tend to cluster animals according to their environmental context. For body parts, the analysis showed more parts, particularly internal organs, named with age and a cluster of face parts generated by all age groups. A novel feature of the current research was the use of statistical measures of additive tree similarity. The results are discussed with respect to theories of developmental change in the organization of conceptual memory, and are viewed as supporting an assumption of continuity with age in the use of schematic relations in category structure. Insights are drawn from connectionist modeling to help explain the persistence, throughout childhood, of early forms of memory organization.

Introduction

How does the structure of conceptual memory change during the early school years? Between the ages of five and ten children show a massive increase in knowledge—they know more concepts (Clark, 1995), they know much more about the relationships between concepts (Kail, 1990), they make more inferences on the basis of their conceptual knowledge (Paris, Lindauer & Cox, 1977), and they make more sophisticated ontological distinctions (Keil, 1983). The nature of children's conceptual knowledge also appears to change. For instance, younger children show a bias towards organizing concepts *schematically* (or *thematically),* that is, in relation to event or scenes (Nelson & Gruendel, 1981; Mandler, 1983; Nelson, 1983), whilst older children and adults seem to think of concepts primarily in terms of their similarity (functional or perceptual) to each other, that is, in terms of their *taxonomic* relations (Bjorklund, 1985; Lucariello, Kyratzis & Nelson, 1992). As they grow older children also make different inferences on the basis of their knowledge or 'theories' about the world (Carey, 1985), and appear to have more and better strategies for storing and retrieving conceptual information (Kail, 1990).

An important and enduring question with regard to many of these changes is whether they involve a radical reorganization of conceptual memory, or whether they arise from more continuous and incremental forms of change in which new information is assimilated to earlier memory structures that retain key aspects of their original form (Mandler, 1983; Eimas, 1994). In this article we use children's production of animal and body-part terms in the *semantic fluency task* to investigate these questions and report findings that support a view of continuity of memory organization over the period studied.

The semantic fluency procedure, also termed *conceptual fluency, freelisting*, or *category production,* requires participants to generate as many exemplars of a category as possible in a given length of time. When a word or concept is activated in memory (and then spoken) we assume that it will in turn activate other words or concepts which are semantically similar or associatively related to it. This assumption, which is well supported by evidence from numerous semantic priming studies (see Neely, 1991), implies that the order in which words are produced in the fluency task will provide an indirect measure of the psychological proximity of the items generated. Henley (1969) and Storm (1980) provide additional evidence for this assumption by demonstrating that animals of close psychological proximity (as indicated by other semantic memory tasks such as pair rating, sorting, and verbal association) are named in close proximity in lists. Performance in the semantic fluency task also shows a number of consistent characteristics in both children and adults. First, the rate of production of new items over the duration of the task slows with time following a hyperbolic decline (Gruenewald & Lockhead, 1980; Kail & Nippold, 1984; Grube & Hasselhorn, 1996). Second, items that are more typical of a category tend to be produced with higher relative frequency (i.e. by more subjects) than poorer category exemplars (Henley, 1969; Uyeda & Mandler, 1980; Kail & Nippold, 1984; Grube & Hasselhorn, 1996). Third, the most prototypical category members tend to be produced first, followed by familiar (but not prototypical) items, followed by atypical or unusual items (Kail & Nippold, 1984). Finally, items are generally produced in short bursts of conceptually-related words (Bousfield & Sedgewick, 1944; Gruenewald & Lockhead, 1980). Many of these findings support the view that the arrangement of items in the list reflects important aspects of the underlying conceptual structures.

Several studies have employed the semantic fluency task with the aim of understanding changes in memory organization during childhood (Nelson, 1974; Storm, 1980; Lucariello et al., 1992; Grube & Hasselhorn, 1996), the category of animals being most widely studied.

In the earliest study of this kind, Nelson (1974) found that 5-year olds produced, on average, half as many items as 8-year olds when freelisting nine natural language categories. For the animal category she found that children predominantly respond by naming mammals, with older children naming relatively more non-mammals (species of birds, reptiles, etc.) and members of mammalian sub-classes (e.g. breeds of dogs) than younger children. This finding was interpreted as showing an expansion of the hierarchical organization of the animal category with age. The two groups studied also differed in their most frequent responses with the 8-year olds naming domestic animals (dog, cat, and horse) most often, and the 5-year olds naming wild animals (giraffe, lion, elephant, tiger) with greater frequency.

Whereas Nelson looked at conceptual fluency just in children, Storm (1980) studied the freelisting of the animal category across a much broader ranger or subject groups— children (6- and 9-year olds), teenagers, college students, and zoology PhD candidates. Her results confirmed Nelson's finding of increased productivity with age and educational experience. For each experimental group, and for 25 selected animal terms, Storm also computed a mean inter-item similarity score for all pairs of concept words based on their proximity in the generated lists. This measure was used as input to a hierarchical clustering algorithm that formed tree structures in which the most proximal items named by each group were clustered together. Surprisingly, Storm found no obvious differences between the trees generated in this way for the different groups studied. At all ages, subjects clustered animals predominantly according to their habitat/environmental context. Specifically, farm animals (pig, cow, horse), domestic animals (cat, dog, mouse), and wild/zoo animals (lion, leopard, elephant, giraffe), tended to be grouped together. In this respect even the trees generated for PhD zoology candidates, for whom biological criteria for categorization can be presumed to be highly salient, were not dissimilar from those produced by 6-year old kindergarten children—in all subjects the primary mode of mode of organization in freelisting appears to have been a schematic one.

In a further study comparing young children with adults, Lucariello, Kyratzis, and Nelson (1992) tested 4- and 7- year old children and college students on a semantic fluency task for five categories: clothes, animals, food, furniture, and tools. A hierarchical clustering methodology was again used to elucidate the conceptual structures underlying the lists produced by different age groups, this time analyzing, for each age group, all items produced by at least three subjects in that group. For the 4-year-olds this analysis showed a main cluster of zoo animals, and for the 7-year-olds, clusters composed of domestic animals, zoo animals, forest animals, and aquatic animals. For the adults, the analysis revealed a substantial number of clusters that could again be classified in terms of habitat/environmental context, with a cluster of 'primates' (not present in the children's productions) that included humans. Whilst the use of environmental context in many of these clusterings was again interpreted as showing conceptual organization by schematic (i.e. event-based) relations, Lucariello et al. also interpreted their results (together with those for categories) as supporting an increase in the use of conventional taxonomic relations with age.

Finally, Grube and Hasselhorn (1996), looked at the performance of 8-year olds, compared with older children, on the semantic fluency task for the animal category. They found that both age groups clustered items in terms of environmental context (confirming earlier findings), and produced similar typicality structures; that is, the same animals were named at high frequency at both ages. Interestingly, the degree of environmental clustering in the lists of these children was related to productivity (the total number of items generated) only for the older group. This finding was interpreted as showing that some 10-year olds use strategies that exploit the organization of their conceptual memory structures to allow more effective memory retrieval. These researchers also found an increase in the use of strong inter-item associations (e.g. dog—cat, lion—tiger) in older children, a factor which was again linked with greater productivity and strategy use.

In summary, much of the previous work on developmental change in the semantic fluency task has emphasized quantitative rather than qualitative change in the category lists generated by children—older children generate more items (possibly making more use of strategic retrieval processes) but appear to cluster semantic knowledge in similar ways to their younger counterparts. However, data on the youngest children (4-6 year olds) is limited with only three studies performed to date that have generated somewhat inconsistent results. Nelson (1974) found changes in typicality ratings (production frequencies) between 5- and 8-year olds, and has argued for an increase in the hierarchical organization of conceptual knowledge of this time period, Storm's results indicated no clear differences in memory organization between 6-year-olds and older children, while Lucariello et al. (1992) found evidence to support both continuity in the use of schematic (spatiotemporal) relations with age, and some evidence of increased use of taxonomic relations with age. Considered within the wider frame of semantic memory research, these studies also stand in interesting contrast to research that suggests significant changes in the organization of conceptual knowledge over the same time period (see Bjorklund, 1985; Carey, 1985 for review).

One possible limitation of the research described above is that the pattern of results obtained with the frequently studied category of animals may not provide a representative picture of general conceptual change in semantic memory. Although, Lucareillo et al. (1992) found similar results across three categories (food, animals, and clothes), they also found ambiguous and somewhat inconclusive results for two other categories (furniture and tools) that are poorly developed in young children. The current study therefore investigated a further category of conceptual knowledge that is well represented in young children's vocabulary and may undergo significant development between the ages of 5 and 10. Specifically, we examined semantic fluency for the category of human *body parts*. Substantial changes in children's knowledge of body parts (particularly internal ones) are known to be occur within this age range (Gellert, 1962), and it has been suggested (Carey, 1985) that a major shift in the understanding of the body occurs between the ages of eight and ten as children develop intuitive 'biological' theories of how the body works. Since the body parts category has received little attention in studies of children's semantic fluency, yet remains a subject of considerable theoretical interest (see, e.g. Jaakkola & Slaughter, 2002), an investigation into its conceptual structure as revealed by the freelisting task seems timely.

Methodological innovations in the current study

The current study was designed to look for specific evidence of continuity or change, between the ages of 5 and 10, in the conceptual memory structures underlying semantic fluency for the animals and body parts categories. Our basic methodology is similar to Storm (1980) and Lucariello et al. (1992) in that we employ cluster analysis techniques; however, relative to these other studies we have made a number of innovations.

First, Storm (1980) analyzed the same 25 animal concepts in all groups. These were animals that a majority of the youngest children were able to name in a separate picture naming task rather than those which occurred with high frequency during the fluency task. This restriction clearly excludes from the analysis any differences between age groups arising from changes in production frequencies and therefore may obscure significant developmental change. In contrast, Lucariello et al. (1992) analyzed different sets of items at each age group, with the selection of items based on their production frequencies. Relative to Storm's procedure this methodology is likely to highlight differences and mask continuity between age groups. The present study focuses, therefore, on the most frequent responses made during the category fluency task both *within* and *across* age groups, so that the data can be appropriately analyzed for both similarities and differences between groups.

Second, most previous studies have used the distance between items within lists as their measure of inter-item similarity for input to a hierarchical clustering algorithm. However, a second factor of potential significance for estimating similarity, which is largely over-looked in fluency studies, is the number of times, over a group of subjects, that two items are mentioned together. In particular, when each subject generates a relatively small number of items overall, we propose that items which have a high psychological proximity will be more likely to *co-occur* in lists than items with low proximity. We have therefore developed a measure of inter-item similarity based on both within-list proximity, and across-list item co-occurrence. We propose that this combined measure, which is derived analytically using expected probability distributions, provides a robust estimate of inter-item similarity that is particularly appropriate for analyzing fluency data from children of 6 years of age or less whose category listings often contain fewer than ten items.

Third, to perform the hierarchical cluster analyses we have used the additive tree (*addtree*) algorithm developed by Sattath & Tversky (1977). In comparison to some other hierarchical clustering techniques, the addtree technique places fewer a priori constraints on the relationships between items and can therefore provide a more faithful representation of the data. A further limitation of studies using hierarchical clustering is that comparisons between trees are generally made on a qualitative basis. A unique feature of the current study is that we have used the B_k measure devised by Fowlkes and Mallows (1983) to provide appropriate statistical measures of the similarities between two hierarchical clusterings.

Methods

Participants

The subjects for this study were 155 children from two schools, both in Sheffield, UK. These children are predominantly from white, urban families of social class II and III. The children were divided into three groups on the basis of age/school year group: 50 children in year 1, mean age 5:9 years, range 5:1 to 6:4; 55 in year 3, mean age 7:7, range 7:0 to 8:3; and 50 in year 5, mean age 10:0, range 9:0 to 10:4. All of the children spoke English as their first language. All subjects completed the semantic fluency task for both the animals and body parts categories, the additional categories of food items, clothes, vehicles, and plants were also tested, and summary statistics for these other categories are reported below. The order in which categories were listed was randomized across subjects.

Administration of Semantic Fluency Tasks

The children were tested individually at school, in a quiet area. For each category, each child was asked to "Tell me all the _______s you can think of". A one minute interval was allowed for each category. Although some previous studies have allowed a longer time period, the one minute interval was selected here on the basis that subjects generate items at a much quicker rate early on in the fluency task, and also tend to generate more typical items toward the start of the task. Pilot studies also indicated that some of the youngest children found it difficult to focus on the task for more extended periods. Identical instructions were used with all the children, however, the younger children sometimes required encouragement. Where encouragement was given, care was taken not to influence the child's responses. An example would be "Can you think of any (more) _______s?" or "Which other ________s do you know?" Finally, children were asked to shut their eyes throughout the body parts task so that they would be unable use their own body, or that of the experimenter, as a visual cue.

Obtaining Similarity Scores

The fluency tasks provided separate lists of category items for each child, in production order. For each category, and each year group, matrices of inter-item similarities were derived using a metric we have developed to control for differences in production frequency between items and age groups. This metric has two component measures, termed α and β_w below, one based on within-list item proximity (α) the other on across-list item co-occurrence (β_w). In the following we describe how each measure is calculated and then combined to form the overall inter-item similarity metric $\alpha\beta_w$. Note that for all of the measures defined here, increasing value indicates *decreasing* similarity (or increasing dissimilarity).

The measure, α, of within-list item proximity is defined first. Let *a* and *b* be two non-identical category items that occur at the index positions i_{al} and i_{bl} in the category list *l*, containing n_l total items, generated by a given participant. Assume, initially, that *a* and *b* each occur only once in list *l*; in this case we define the normalized inter-item distance between *a* and *b* as the absolute value of the distance between the two items in the list divided by the total length of the list, i.e.

$$\left|\frac{i_{al} - i_{bl}}{n_l}\right|.$$

Using n_l as a normalization term is appropriate here since the expected probability distribution for values of $i_{al} - i_{jl}$ has a standard deviation that increases in an approximately linear manner with list length[i].

Participants sometimes repeat one or more items when generating a category listing. If either of the items *a* or *b* is repeated in list *l* we choose our measure of inter-item distance d_{abl} to be the smallest of all such distances

$$d_{abl} = \min_{\forall a,b \in l}\left(\left|\frac{i_{al} - i_{bl}}{n_l}\right|\right).$$

However, the expected probability distribution will also be significantly narrower for repeated items, so it is appropriate in this situation to include an additional scaling term. Let n_{al} and n_{bl} be the number of occurrences of *a* and *b* respectively in list *l*. Based on an analysis of the relevant expected probability distributions, we have found that a suitable scaling term[ii] is given by $\lambda(n_{al}n_{bl})$ where $\lambda(1)=1.0$, $\lambda(2)=0.67$, $\lambda(3)=0.5$, $\lambda(4)=0.41$, $\lambda(6)=0.28$. These values cover all the occasions of repeated items in our data-set.

Let F_{ab} be the total number of subjects in a given group whose responses contained the pair *a* and *b*. *W*e can now define α such that

$$\alpha(a,a)=0, \quad \alpha(a,b)=\frac{1}{F_{ab}}\left(\sum_{l(a\in l\wedge b\in l)} d_{abl}/\lambda(n_{al}n_{bl})\right).^{**}$$

In other words, α provides a measure of inter-item similarity that is zero (maximally similar) between an item and itself, greater than zero for all non-identical items *a* and *b*, and increases with the normalized inter-item distance between *a* and *b* averaged over all participants who named both items at least once in their category list.

Next we define the second measure of inter-item similarity, β_w, based on across-list item co-occurrence, which can be combined multiplicatively with α to form the overall inter-item similarity metric $\alpha\beta_w$.

Let f_a and f_b be the number of participants in the group naming items *a* and *b* respectively, and let *N* be the total size of the group. The expected number of co-occurrences of items *a* an *b* is then given by[iii]

** Corrected from the published version.

$$E(F_{ab}) = \frac{f_a f_b}{N}.$$

We now calculate the normalized number of co-occurrences as the difference between this expected value and the observed value F_{ab},

$$C_{ab} = E(F_{ab}) - F_{ab}.$$

Let the maximum and minimum obtained values of C_{ab} for a given group of participants be C^+ and C^- respectively, and let $S = 1 + \max\left(C^+, \left|C^-\right|\right)$. β is now defined as

$$\beta_w(a,a) = 0, \quad \beta_w(a,b) = 1 + w\frac{C_{ab}}{S}.$$

Here S provides a scaling factor[iv] such that $-1 < C_{ab}/S < +1$ for all a and b, and w ($0 \le w \le 1$) is a weight used to determine the relative contribution of β_w to the combined measure of item similarity $\alpha\beta_w$. Note that β_w will be equal to 1 if the observed number of co-occurrences matches the expected frequency, thus making no net contribution to $\alpha\beta_w$. If the number of co-occurrences is greater than expected, β_w will be less than 1 reducing the overall metric proportionately. Finally, if the number of co-occurrences is less than expected, β_w will be greater than 1 thereby increasing the size of $\alpha\beta_w$. As the number of participants naming either item *a* or *b* approaches N (the size of the group), C_{ab} becomes a less useful indicator of psychological proximity (to see this, observe that at $f_a = N$ the variance in C_{ab} will be zero, every occurrence of item *b* will necessarily be a co-occurrence with item *a*!). However, in such situations β_w will take a value close to 1, giving a combined similarity metric $\alpha\beta_w$ that depends almost entirely on the within-list proximity measure α. It is therefore appropriate to use β_w as part of a combined measure regardless of the expected frequency of individual category items.

In the addtree analyses reported below all matrices of similarity data were generated using the metric $\alpha\beta_{0.5}$ as the value w= 0.5 was found to generate a suitable balance between the α and β for all categories and groups[v].

Results

Age related trends in productivity and production frequencies (typicality) are described first, followed by the addtree analyses of category structure. *Except where stated all results are significant at $p<0.01$.*

Productivity

One-way ANOVA revealed substantial overall increases with age in the mean number of responses generated for all categories. The means, standard deviations and F-values are shown in table 1. Post hoc tests (Fisher's PLSD) showed significant increases in the mean number of items produced with increasing age in all categories, except between year 3 and year 5 groups for the clothes category (for the vehicles category the difference between year 3 and year 5 was significant at $p<0.05$). There were also significant differences between the number of items listed in the different categories for all three year groups (repeated measures ANOVA: Year 1, $F(5)= 39.82$; Year 3 $F(5)= 51.86$; Year 5, $F(5)= 68.95$). In all years, the body parts category generated the most responses followed by the animals category, clothes and foods generated an intermediate numbers of responses, and vehicles and plants the fewest. In view of the higher productivity for animals and body parts, and the theoretical importance of these two categories as outlined in the introduction, the remaining analyses focus on these two categories exclusively.

**** TABLE 1 ABOUT HERE ****

Production frequencies

The production frequency for any given category item is calculated as the proportion of children in a selected group who named that item at least once. Tables 2 and 3 show, for each of the three year groups, the production frequencies of items in the animals and body parts categories generated by at least 20% of the children in that group.

For each category, product-moment correlations were calculated for the production frequencies of the items named by a least 5% of participants in all age-groups (there were 34 such items in the animals category, 28 in the body parts category). For the animals tasks this gave the correlations: Year 1 and Year 3 $r(32) = 0.84$, Year 1 and Year 5 $r(32) = 0.77$, Year 3 and Year 5 $r(32) = 0.78$. For the body parts task Year 1 and Year 3 $r(26) = 0.89$, Year 1 and Year 5 $r(26) = 0.63$, Year 3 and Year 5= 0.83. The strength of these correlations indicates considerable similarity between the typical responses generated by the different year groups.

Significant correlations were also found with the results of previous semantic fluency studies (Posnansky, 1978; Grube & Hasselhorn, 1996). For instance, Posnansky (1978) calculated production frequencies for 25 different categories including animals and body parts for children in grades 2, 3, 4, and 6, for a 1-minute, written, freelisting task. Comparing the year 3 and year 5 groups in the current study with the nearest equivalent groups in Posnansky's study (Grades 2 and 4 respectively), gave correlations for the animals task of $r(17) = 0.80$ (year 3 and grade 2) and $r(20) = 0.74$ (year 5 and grade 4), and for the body parts task of $r(19) = 0.79$ (year 3 and grade 2) and $r(19) = 0.59$ (year 5 and grade 4).

Morrison, Chappell, and Ellis (1997) have provided estimates of the age of acquisition of many of the animal terms investigated here. Production frequencies of animals terms from the current study showed a significant negative correlation with their 'objective age of acquisition (75%)' measure for all three age groups—year 1 $r(22) = -.48$ ($p<0.05$), year 3 $r(22) = -0.57$, and year 5 $r(22) = -.57$. This result indicates that some of the most frequently produced responses for the animal category are also those that are acquired first.

Finally, comparisons were made with adult typicality ratings[vi], collected by Uyeda and Mandler (1980), for items in the categories ‘four-footed animals’ and ‘parts of the human body’. This gave the correlations: for the animals category, year 1 $r(16)= -0.68$, year 3 $r(16)= -0.57$ ($p<0.05$), and year 5 $r(16)= -0.59$; and for the body parts category, year 1 $r(18)= -0.73$, year 3 $r(18)= -0.82$ ($p<0.05$), and year 5 $r(18)= -0.67$. Thus, production frequencies, at all ages, appear to provide a good indication of item typicality at least with respect to adult norms.

**** TABLE 2 ABOUT HERE ****

**** TABLE 3 ABOUT HERE ****

Composition of category data

Following Nelson's (1974) finding that 8-year-olds name more non-mammals than 5-year-olds, the ratio of non-mammals to total animals was compared across age groups. This measure, with group medians (ranges) of 0.20 (0–0.67) for year 1, 0.22 (0–0.83) for year 3, and 0.29 (0–0.77) for year 5, indicated that all age groups named mammals predominantly, and that older children named significantly more non-mammals (Kruskal-Wallis[vii] $H(2)=6.17$, $p<0.05$, sum of ranks= 3362.0, 4254.0, and 4474.0 for years, 1, 3, and 5 respectively).

Nelson also noted a predominance of 'wild' animals in the top five responses of 5 year olds (*giraffe*, *lion*, *elephant*, *tiger*, horse). In the current study the top five of the year 1 group (mean age 5.9) includes two wild animals (*lion*, *tiger,* cat, dog, horse). However, from table 2 it is clear that the older children also name some 'wild' animals with high frequency. An interesting trend in the current data-set is the apparent increase in typicality with age for two domestic animals, *cat* and *dog*, relative to other animal terms. Specifically, in the year 1 group, the average production frequency for these animals (0.46) is only slightly greater (0.06) than the average production frequency for the overall top ten items (0.40). In years 3 and 5, however, the same comparison shows a difference of 0.22 (0.68 - 0.46), and 0.26 (0.87 - 0.61) respectively. This difference suggests that between the ages of 6 and 8 there may be a substantial increase in the status of *cat* and *dog* as prototypical animals.

Carey (1985), following Gellert (1962) and others, has argued for a significant change in children's conceptual understanding of internal body parts between the ages of 8 and 10. Data from the current study was therefore analyzed to determine the ratio of internal organs[viii] (i.e. heart, brain, lung, etc.) to total body parts named by each age group. This measure, with group medians (ranges) of 0.0 (0–0.5) for year 1, 0.07 (0–0.75) for year 3, and 0.21 (0–0.64) for year 5, indicated a significant increase with age, with year 5 children in particular, naming many more internal organs than the youngest group (Kruskal-Wallis: $H(2)=38.78$, $p<0.01$, sum of ranks= 2749.0, 3963.5, and 5377.5 for years, 1, 3, and 5 respectively).

Representing category structure

Several addtree analyses were carried out for each of the category/group $\alpha\beta_w$ similarity matrices using the ADDTREE/P program written by Corter (1982). First, we were interested in analyses that revealed the conceptual structure of children's knowledge, taking into account increasing productivity and changes in production frequency with age. Target concepts for these within-group analyses were chosen on the basis that they had been produced by at least 20% of the children in the particular age group being considered. In order to perform these analyses items were excluded if they failed to co-occur at least once with each of the other items in the set, since, under these circumstances, a full matrix of inter-item distances cannot be computed. For this reason a small number of the items that appear in Tables 1 and 2 are excluded from the corresponding addtree analyses. Second, we wanted to allow direct comparison of related conceptual structures across age groups. Target concepts for these analyses were chosen on the basis that they had been produced by at least 20% of participants in the youngest age group (year 1), and co-occurred at least once in all three groups.

Interpreting Addtrees

Several factors are of note when interpreting addtrees.

First, a tree's 'goodness of fit' to the data is expressed as a stress value (the measure reported is Kruskal's stress measure) ranging from 0 (best possible fit) to 1 (worst possible fit). High stress values may indicate that a tree is not an adequate representation of the similarity structure of the data. The statistic r^2 is also reported, which provides a measure of the proportion of the variance of raw distances (i.e. the matrix of similarities used as input to the analysis) that is accounted for by the distances shown in the tree, thus tree representations which most accurately fit the data will have low stress values and high r^2 values.

A second factor for consideration is the division of concepts into clusters. Each addtree is composed of nodes (horizontal lines in the figures displayed below) and arcs (vertical lines). Concepts are represented by external nodes and are formed into clusters by internal nodes; all nodes are joined by arcs. The distinctiveness of a cluster and the degree of similarity within a cluster are both indicated by the length of nodes, with the shortest lengths indicating the greatest similarity. For any two items in the tree, their inter-item similarity is indicated by the sum of the lengths of the nodes in the path between the two items (again shorter= more similar). Note that the length of arcs has no significance.

Finally, in comparing across age groups, some measure is needed of the similarity of two trees with identical sets of external nodes but different internal structure (note, no statistical measures exist for comparison of trees with different sets of external nodes). Two trees may be similar at one level of clustering but dissimilar at another, for this reason we have used the statistic B_k developed by Fowlkes and Mallows (1983), which provides multiple measures of similarity at different levels of clustering. Further explanation of the calculation and interpretation of the B_k statistic is given below.

Analysis of Conceptual Structure for the Animals Task

Figure 1 shows addtree analyses of animal names for all three year groups, where items were selected, for *each* year group, on the basis that they were listed by at least 20% of the children in that group (year 1 stress = 0.094, r^2 = 0.712; year 3 stress = 0.072, r^2 = 0.702; year 5 stress = 0.079, r^2 = 0.660).

**** FIGURE 1 ABOUT HERE ****

In accordance with previous findings (Storm, 1980; Lucariello et al., 1992; Grube & Hasselhorn, 1996) these analyses show that typical environmental context is a key organizing factor in children's freelisting of the animal category. In year 1, two major clusters are evident containing domestic/farm animals (*cat, dog, cow, horse, sheep, pig*) and wild/zoo animals (*elephant, giraffe, monkey, lion, tiger*). Farm animals form their own distinct sub-cluster within the larger domestic/farm animal group. Year 3 shows a cluster containing domestic pets (*cat, dog, rabbit, hamster, mouse*), and, within the second branch of the main tree, sub-clusters of wild/zoo animals (*elephant, giraffe, lion, tiger, kangaroo, monkey*), farm animals (*horse, cow, sheep, pig*), and aquatic animals (*fish, dolphin, shark, whale*). Finally, the year 5 tree again has a large cluster of predominantly wild/zoo animals (*giraffe, elephant, monkey, lion, tiger*), a cluster of farm animals (*horse, cow, pig, sheep*), and several smaller clusters including the pairs (*cat, dog)*, (*mouse, rat),* (*hamster, snake),* and the triplet (*fish, fox, rabbit)*. Whilst the interpretation of some of these smaller clusters is less obvious (*fish, fox, rabbit,* for instance could be a collection of British wild animals), the general trend toward clustering by environmental context seems clear. The term *bird* appears in all three trees but is not consistently clustered with a specific group, perhaps because of its status as a super-ordinate class that includes animals falling into many different schematic categories.

Figure 2 shows addtree analyses of animal names for all three year groups, where items were selected, for *all* year groups, on the basis that they were listed by at least 20% of the children in the year 1 group and co-occurred at least once in all three year groups (year 1 stress = 0.094, r^2 = 0.712; year 3 stress = 0.064, r^2 = 0.854; year 5 stress =

0.079, $r^2 = 0.862$). Note that, for the year 1 group, the trees generated for this analysis and the previous one in Figure 1 are identical.

**** FIGURE 2 ABOUT HERE ****

In each tree in Figure 2 the internal nodes are numbered according to the number of clusters (k) formed if the tree is split below that point. For example, for the Year 1 tree, the dotted line in Figure 2 shows the decomposition of the tree into k= 2 clusters. The comparison statistic B_k, devised by Fowlkes and Mallows (1983), provides a measure of the similarity of two trees at each level of clustering[ix] for k= 2, …, n-1, where n is the number of objects in the tree. B_k varies between 0, maximum dissimilarity, and 1, maximum similarity. The graphs at the base of Figure 2 show plots of B_k for the comparisons, from left to right, Year 1 with Year 3, Year 1 with Year 5, and Year 3 with Year 5. Values of B_k are shown by the diamond-shaped point plots for k= 2, …,11. The solid line and the two dotted lines on each graph show, respectively, the expected value of B_k and its upper and lower limits. Values of B_k outside the range indicated by these limits can be considered significant[x]. On average, two-thirds of the B_k scores (7/10, 8/10, and 5/10 in the three comparisons) lie above the upper limit of their expected values, indicating that the trees generated for all three groups in this task are similar at many levels of clustering.

Analysis of Conceptual Structure for the Body Parts Task

Figure 3 shows addtree analyses of body parts for all three year groups, where items were selected, for *each* year group, on the basis that they were listed by at least 20% of the children in that group (Year 1 stress = 0.080, r^2 = 0.740; Year 3 stress = 0.085, r^2 = 0.800; Year 5 stress = 0.072, r^2 = 0.708).

**** FIGURE 3 ABOUT HERE ****

The children in all years distinguished a cluster of internal parts (e.g *bone, heart*) and a cluster of face parts (e.g. *eye, nose, mouth*), The addtree analysis clearly illustrates children's increasing knowledge with age of internal parts of the body. Year 5 children named many more internal body parts than the younger age groups; furthermore, the addtree analysis for this group shows some internal organization within the cluster of internal parts, specifically, associated pairs of internal organs (*heart—lung* and *liver—kidney*), and muscular-skeletal parts (*bone—muscle*). The associative pair (*arm—leg*) appears consistently in all year groups, digits (*finger, toe*) either cluster with each other or within the appendages to which they attach (*hand, foot*). A group of body parts than can be thought of as joints or connectors form a distinct cluster in the year 3 group (*elbow, shoulder, knee, and neck*), but appear as two separate pairs at year 5 (*elbow, knee)* and (*shoulder, neck*). In the year 1 group *neck* is clustered with '*tummy'* (the most popular term amongst younger children for the abdomen) perhaps on a similar basis that they are both 'connecting' parts.

Figure 4 shows addtree analyses of body parts for all three year groups, where items were selected, for *all* year groups, on the basis that they were listed by at least 20% of the children in the year 1 group and co-occurred at least once in all three year groups (year 1 stress = 0.082, r^2 = 0.736; year 3 stress = 0.082, r^2 = 0.828; year 5 stress = 0.081, r^2 = 0.862). Graphs of the B_k statistic are also shown for the comparisons, from left to right, year 1 with year 3, year 1 with year 5, and year 3 with year 5. As with the animals category, a two-thirds majority of B_k scores lie above the upper limit of their expected values (8/13, 7/13, and 11/13 in the three comparisons) indicating similarities at many levels of clustering between all three year groups.

**** FIGURE 4 ABOUT HERE ****

Discussion

The semantic fluency task cannot provide exhaustive access to a children's category knowledge, and, in the somewhat abbreviated form used here, is unlikely to provide access to even a majority of the concepts a child knows for any given category. What it can reveal, however, is what items of a category spring most easily to mind, and thus, in some sense are most typical of that category, and what items within a category are most strongly linked and are therefore likely to be recalled together. In this discussion we first summarize the findings for the two different categories studied (animals and body parts), and then consider the validity and generality of the results as reflections of the organization of conceptual structure in memory. We then consider the implications of these findings for a number of influential theories of conceptual memory development. Finally, we suggest a possible explanation for the pattern of results shown based on insights from connectionist modeling of memory acquisition.

Development of semantic fluency for the animals category

The degree of similarity across age groups both in terms of production frequencies (as a measure of typicality) and clustering (as shown by the addtree analysis) suggests an underlying continuity in the organization of memory for animal concepts. This study also confirms the finding that children from an early age tend to cluster animals primarily in terms of their typical environmental context (i.e. where animals are experienced or might be expected to be experienced). Although older children know and list significantly more animals, this primary mode of clustering is maintained. Thus, 8- and 10-year-olds named more non-mammals, but these were clustered together with mammals found in similar contexts, for instance, *kangaroo* was found clustered with *monkey* (both wild/zoo animals), while *fish* and *shark* shared an aquatic cluster with *dolphin* and *whale*. There was little support for Nelson's (1974) suggestion of general change, between 5 and 8 years, in the most frequently produced items from wild animals to domestic animals. The current data suggest instead, a more focused increase with age in the relative frequency of two specific domestic animals—*cat* and *dog*—implying that these animals are increasingly considered to be prototypical. Since Nelson's subjects were slightly younger than those investigated here (mean age 5.1 years compared to 5.9 years for the current year 1 group), the prototypicality of domestic animals for young children may warrant some further investigation.

Development of semantic fluency for the body parts category

Production frequency data for the body parts task also showed substantial similarities across age groups. Children at all ages generated a cluster of internal body parts, and a cluster of face parts separate from clusters of other body parts. In addition to the expected increase in the number of body parts named with age, the oldest children also generated a much large cluster of internal body parts and organs than the younger children. The basis of clustering for body parts suggest two underlying dimensions of organization. The first is a topological basis for clustering (that is naming parts that are close together), based around a principle distinction between the head and the trunk. The second is organization according to function, this is evident in the clustering of limbs (*arm—leg*) and in older children of 'joints' (*elbow, knee, shoulder*), digits (*finger—toe*), and related internal parts (*heart—lung*, *kidney—liver*, and *bone—muscle*). The presence of an increasing number of such functional associations in the older children suggests that this dimension of organization may become of greater importance with age, although further research is needed to establish whether there is a reliable, age-related trend.

Validation of results

One of the most effective techniques for validating cluster analyses is replication (Aldenderfer & Blashfield, 1984). Similar results for the animal category found in other studies (Storm 1980; Lucariello et al, 1992; Grube & Hasselhorn, 1996) demonstrate that the finding of clustering by environmental context in the animals task is a robust and repeatable one. A second group of children tested by the authors on both the animals and body parts tasks also showed similar results to those reported here (Hartley, 1999).

A second means of validation is by comparison with other methods of analysis. Several studies have looked at semantic fluency data for the animals category using multidimensional scaling (MDS) techniques (Henley, 1969; Chan et al., 1993). MDS attempts to find a small number of principle dimensions that are able to provide a good fit to a matrix of inter-item distances. Results from studies that have been successful in using MDS with adult animal fluency data generally complement the findings of hierarchical clustering. Thus, for instance, Chan et al. (1993) found a principle dimension corresponding to a wild/domestic distinction in semantic fluency data (1993), and a second dimension corresponding to size, while Henley (1969) found principle dimensions of 'ferocity' and 'size', but also noted clusters of wild and domestic animals in animal semantic space.

Generality of results

An important question is whether the results of these semantic fluency studies reflect generic properties of the structural organization of conceptual memory or merely indicate characteristics of memorial processes that are specific to freelisting tasks. Support for a generic, rather than task-specific, view comes from the studies of Henley (1969) and Storm (1980) who have shown that semantic memory tasks such as pair rating, sorting, and verbal association produce similar results to the semantic fluency task for the animals category. To further investigate the generality of the current study, Roberts and Hartley (described in Hartley, 1999) asked children to provide similarity ratings for the twelve animals with highest production frequency in the semantic fluency task. Three groups of children were tested, taken from years 1, 3, and 5 of a UK primary school (i.e. the same age groups as in the fluency study). Addtree analyses of the resulting similarity matrices showed that the principle basis for clustering in each age group was environmental context, showing good agreement with the results of the freelisting task. A tendency to sub-cluster items by size, as described by Chan et al.(1993), was also evident, particularly for the oldest group (e.g. *elephant—giraffe*, *horse—cow*). Full details of this study are given in Hartley (1999).

Production frequencies in the current study were consistent with those of other fluency studies and, more interestingly, showed good correlations with norms for 'age of acquisition' and adult typicality. These findings therefore provide strong support for the assumption that production frequencies in the semantic fluency task reflect the typicality of category members, and are not simply an artifact of the freelisting paradigm. Bjorklund and co-workers (Bjorklund, Thompson & Ornstein, 1983; Bjorklund, 1985) found that children's judgments of typicality become more similar to those of adults with age. Such a trend is not evident here in the comparison of production frequency data to adult typicality ratings. Bjorklund et al.'s findings have, however, been called into question by more recent evidence showing that young children often misunderstand the task of providing typicality judgments (Maridaki Kassotaki, 1997).

A possible source of task-specific effects in the semantic fluency task is the use of meta-memorial strategies. For instance, Grube and Hasselhorn (1996) have suggested that increased productivity in word generation behavior could reflect the use, in older children, of specific strategies that would make their recall more efficient. Thus, for instance, children may purposefully decide to produce as many farm animals as they can, or name parts of the face as they can think of, etc. Although there is good evidence that older children are more able to use strategies to aid their recall, Bjorklund (1985) has pointed out the use of such strategies depends upon, and is supported by, conceptual knowledge. Thus evidence of strategy use is not incompatible with the assumption that freelisting behavior reflects category structure.

Implications for theories of conceptual memory development

Mandler (1983) has reviewed evidence suggesting that the conceptual knowledge of young children is organized *schematically,* that is, in terms of the sort of relationships (such as temporal or spatial contiguity) typically found in events, stories, or real-world scenes. Nelson and her co-workers (Nelson & Gruendel, 1981; Nelson, 1983; Nelson, Fivush, Hudson & Lucariello, 1983; Lucariello et al., 1992) have made a similar proposal, suggesting that young children's conceptual memory is organized around representations of events, or life experiences, termed *scripts*. A substantial body of research (see Mandler, 1983; Bjorklund, 1985 for review) suggests, however, a shift in knowledge organization with age away from the use of schematic relations and towards *taxonomic* ones, that is relations based on the similarity of perceptual and functional attributes (though see Lin and Murphy (2001) for evidence of the use of schematic relations in adults).

A further proposal for significant change in conceptual organization between ages 5 and 10 has been made by Carey (1985). Carey argues that children below the age of 8 lack a biological framework with which to structure their understanding of either the body, and the operation of its parts, or the animal kingdom, and the relations between its members. Instead, young children rely on 'psychological' theories of the body, in which bodily processes are accounted for in terms of what a person 'wants or thinks', and make inferences about animals on the basis of their perceived similarity to people rather than any understanding of the biological relatedness of different animal kinds. By age 10, Carey suggests that children have come to regard themselves as biological organisms and have attained a new functional understanding of internal bodily processes. The development of this 'intuitive biology' also results in an understanding of the animal kingdom based on biological inter-relatedness rather than similarity to humans.

The issue with respect to the current study is not whether there is an increased use of taxonomic relations with age, or a significant change in children's theoretical understanding of biological categories. There is, indeed, persuasive evidence in favor of both of these proposals. Instead we are concerned here with what these changes might imply for the organization of conceptual knowledge structures.

With regard to the category of animals, the finding of clustering by environmental context is consistent with a primary basis for category organization based on schematic relations. Thus, animals appeared to be encoded in terms of the places in which they are experienced (i.e. in the home, on a farm, in a zoo, etc.), and are most closely related to other animals experienced in similar locations. Significantly, this same basic structure seems to underlie the animal knowledge of all age groups. Therefore, although older children may have more sophisticated knowledge of animals, that may include increased understanding of taxonomic relations, there is little to suggest a radical upheaval with age in the way that this category knowledge is organized. The findings of increased proportions of non-mammals and invertebrates in the animal freelistings of older children are consistent with suggestions of the expansion (Nelson, 1974; Anglin, 1977) or redrawing (Carey, 1985) of the boundaries of this category with age. Changes in category boundaries might themselves be expected to bring about re-organization of internal category structures. The current study suggests, however, that redrawing the boundaries of the animal category has a more or less incremental effect on its internal organization; that is, such changes are accommodated through the addition of new environmental contexts, or the inclusion of new category members in existing context groupings.

For the body parts category, the current study suggests a primary organization of external parts based on the differentiation of face/head parts from trunk/limb parts. Since a schema for the face is thought to develop in infancy (Gibson & Spelke, 1983), this finding is also consistent with the proposal that schematic relations form the main substrate of conceptual representations of young children. There was also some evidence that taxonomic (functional) relations may play a role in the sub-cluster organization of external body parts especially in the older age group.

Younger children in our study generated only a small number of internal body parts, and there was insufficient information in the fluency data to determine whether these are organized in any structured way. In contrast the oldest children in our sample (9 and 10 year olds) generated a substantial cluster of internal body showing some evidence of internal structure according to function. This data would appear to consistent with Carey's assertion that between the ages of eight and ten children development new representations of the insides of the human body based on a functional understanding of bodily processes.

Continuity and Change in Category Structure

How can we make sense of the apparent persistence of early forms of memory organization in the face of significant theory change and increased familiarity and use of taxonomic relations with age? Research on connectionist models of human memory (Rumelhart & Todd, 1992; Elman, 1993; McClelland, 1994; Hartley, Prescott & Nicolson, 1998), since it allows the investigation of learning trajectories, suggests one possibility. The landscape of possible network configurations for a neural network usually contains many local optima—configurations that are better than other nearby solutions but do not provide a global optimum (the solution that provides the best possible overall 'fit' to the training data). For this reason the early training phase for a network, which is critical in establishing an initial organization, may set limits for later learning (Elman, 1993). Further training, that involves additional or more complex training patterns, will generally promote convergence to a nearby, locally optimal configuration (relative to the previously established pattern of organization), that will accommodate both the old and new data. However, this configuration will generally be quite different from that of a network trained from scratch with the full and final training set. In other words, an early phase of training on a sub-set of data, that emphasizes some properties and not others, is likely to bias the eventual outcome of the learning process.

Viewing the development of conceptual memory from this perspective would suggest a parallel between the early phase of network learning and the establishment of memory structures based on schematic relations. Later learning about taxonomic/functional relations, or changes in the theoretical understanding of concepts, could add considerable refinement and complexity to the pattern of organization without necessarily effecting a major upheaval to its basic structure. A further implication is that if, as Mandler (1983) has suggested, schematic relations "remain the predominant form of organization throughout life" (p. 473), then adult conceptual memory may not be optimally organized with respect to the representation of taxonomic relations. That is, the super-imposition of taxonomic data on a substrate defined by schematic relationships could lead to a degree of compromise in how effectively the taxonomic relations are encoded.

Conclusion

In this article we have examined the development of semantic fluency between the ages of 5 and 10, both for the frequently studied category of animals, and for the relatively unexplored category of human body parts. The use of a hierarchical clustering technique (additive tree analysis) revealed interesting patterns of both continuity and change in children's conceptual structures. For the animals category we have confirmed a tendency to cluster items by environmental context at all ages (resolving some uncertainty particularly with regard to the behavior of the youngest age group investigated). Thus, although there is a substantial increase in children's knowledge over this age range, accompanied by a deepening understanding of biological kinds, this pattern of memory acquisition could be described, following Eimas (1994, p. 85), as "a quantitative enrichment, and not a qualitative transformation of {...} early category representation." For the body parts category the analysis provided here suggests a mixture of continuity and change that we have provisionally interpreted as showing a primarily schematic organization modified by a growing functional understanding of the body (and, in particular, its internal parts). Uniquely, for a study of hierarchical clustering in the development of semantic fluency, these comparisons have been made both within and across age groups and have used quantitative measures of addtree similarity. Finally, we have suggested that the tendency of connectionist models to retain their early organizational structure whilst adapting to represent more complex or detailed information, could provide plausible models for understanding continuity and change in the development of category structure.

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[i] The probability distribution for $i_{al} - i_{jl}$ is a *discrete triangular* distribution with mean 0 and range $-(n_l - 1)$ to $+(n_l - 1)$. This distribution can be approximate by the equivalent *continuous triangular* distribution (range –*n* to +*n*) which has a standard deviation of $\sqrt{6}n$, and therefore increases linearly with *n*.

[ii]Values of $\lambda(n_{al}n_{bl})$ were calculated by (i) generating the relevant probability distributions for different values of n_{al}, and n_{bl}, (ii) calculating the standard deviations over a broad range of values for n_l, and (iii) using linear regression to find a suitable coefficient to estimate the standard deviation as a linear function of n_l. Note, that a linear approximation was found to produce a good fit to this data for $n_{al}n_{bl} \leq 6$.

[iii] The set of possible values for F_{ab} forms a standard *hypergeometric* distribution, for which the expected value is given by the equation shown.

[iv] In theory the standard deviation of the hypergeometric distribution could be used to scale values of C_{ab}, however, this has two drawbacks. First, we would still need to ensure that the values of the scaled C_{ab} fell within a bounded range. Second, as the number of participants naming either item *a* or *b* approaches *N* (the size of the group), the standard deviation of the distribution approaches 0, making it an unsuitable scaling factor for items with very high production frequencies.

[v] Additional analyses were also performed using α and β_1 as separate metrics, the results of these analyses were broadly consistent with the trends described here for the combined $\alpha\beta_{0.5}$ measure.

[vi] Uyeda and Mandler (1980) used a rating scale of 1 (high typicality) to 7 (low typicality), hence the correlations with the production frequencies in the current study are all negative.

[vii] Note, the non-parametric Kruskal-Wallis test is used since many children in all age groups named no non-mammals and consequently the distribution of ratios is highly skewed. Values for H are after correction for ties.

[viii] Internal *organs* were selected for this analysis because of the difficulty of defining internal body parts. For instance, it is not clear whether parts of the mouth (teeth, tongue, etc.) should count as internal or external. Gellert (1962) noted a similar problem in her analysis of children's freelisting of things 'inside' the body.

[ix] The division of a tree into k clusters is dependent on the choice of the root node of the tree. The root node is usually selected to produce a balanced tree, and, in the case of all the trees used in the current B_k analyses, one which minimizes the variance of the distances from the root to the external nodes of the tree. However, other choices for the root node are possible. Clearly, the choice of root node can effect the computation of statistic the B_k statistic. However, experiments with alternative choices of root node (that also produced reasonably balanced trees) showed only a small effect on B_k for the comparisons reported here.

[x] Fowlkes and Mallows (1983) state that these limits provide only an approximate indication of the significance of B_k (i.e. it is not possible to specify a p value) since the distribution of the measure is not normal and successive values are generally correlated.

Figure Legends

Figure 1. Addtree analyses of inter-item similarity data for *animal* terms using items, for *each* year group, that were listed by at least 20% of the children in that group.

Figure 2. Top: Addtree analyses of inter-item similarity data for *animal* terms using items, for *all* year groups, that were listed by at least 20% of the children in the year 1 group and co-occurred in all three year groups. Internal nodes are labeled according to the number of clusters (k) formed when the tree is split below that node. Bottom: Graphs of B_k (x-axis) vs. k (y-axis) for the comparisons, from left to right, year 1 with year 3, year 1 with year 5, and year 3 with year 5. Values of B_k are indicated by diamond symbols, while the plain solid line and the two dotted lines show the expected value and its upper and lower limits for each value of B_k. Values of B_k that exceed the upper limit can be considered significant.

Figure 3. Addtree analyses of inter-item similarity data for *body parts* using items, for *each* year group, that were listed by at least 20% of the children in that group.

Figure 4. Top: Addtree analyses of inter-item similarity data for *body parts* using items, for *all* year groups, that were listed by at least 20% of the children in the year 1 group and co-occurred in all three year groups. Bottom: Graphs of B_k for the comparisons, from left to right, year 1 with year 3, year 1 with year 5, and year 3 with year 5 (see Figure 2 legend for key).

References

Aldenderfer, M. S., & Blashfield, R. K. (1984). *Cluster Analysis*. London: Sage Publications.

Anglin, J. M. (1977). *Word, object, and conceptual development.* New York: Norton & Co.

Bjorklund, D. F. (1985). The role of conceptual knowledge in the development of organization in children's memory. In C. J. Brainerd (Ed.), *Basic Processes in Memory Development*. New York: Springer-Verlag.

Bjorklund, D. F., Thompson, B. E., & Ornstein, P. A. (1983). Developmental-trends in children's typicality judgments. *Behavior Research Methods & Instrumentation*, **15**(3), 350-356.

Bousfield, W. A., & Sedgewick, C. H. W. (1944). An analysis of sequences of restricted associative responses. *Journal of General Psychology*, **30**, 149-165.

Carey, S. (1985). *Conceptual change in childhood*. Cambridge, MA: MIT Press.

Chan, A. S., Butters, N., Paulsen, J. S., Salmon, D. P., Swenson, M. R., & Maloney, L. T. (1993). An assessment of the semantic network in patients with Alzheimer’s- disease. *Journal of Cognitive Neuroscience*, **5**(2), 254-261.

Clark, E. V. (1995). *The lexicon in acquisition*. Cambridge: Cambridge University Press.

Corter, J. E. (1982). Addtree/P - a Pascal program for fitting additive trees based on Sattath and Tversky Addtree algorithm. *Behavior Research Methods & Instrumentation*, **14**(3), 353-354.

Eimas, P. D. (1994). Categorization in early infancy and the continuity of development. *Cognition*, **50**, 83–93.

Elman, J. L. (1993). Learning and development in neural networks - the importance of starting small. *Cognition*, **48**(1), 71-99.

Fowlkes, E. B., & Mallows, C. L. (1983). A method for comparing two hierarchical clusterings. *Journal of the American Statistical Association*, **78**, 553-569.

Gellert, E. (1962). Children's conceptions of the context and functions of the human body. *Genetic Psychology Monographs*, **65**, 293-405.

Gibson, J. J., & Spelke, E. S. (1983). Infant Perception. In J. H. Flavell & E. M. Markman (Eds.), *Cognitive Development*(Vol. 3,). New York: Wiley.

Grube, D., & Hasselhorn, M. (1996). Children's freelisting of animal terms: Developmental changes in activating categorical knowledge. *Zeitschrift Fur Psychologie*, **204**(2), 119-134.

Gruenewald, P. J., & Lockhead, G. R. (1980). The Free Recall of Category Examples. *Journal of Experimental Psychology: Human Learning and Memory*, **6**(3), 225-241.

Hartley, S. J. (1999). *Development of conceptual knowledge: Connectionist and experimental insights*. PhD Thesis, University of Sheffield.

Hartley, S. J., Prescott, T. J., & Nicolson, R. (1998,). *Experimental and connectionist perspectives on semantic memory development*. Paper presented at the Proceedings of Twentieth Annual Conference of the Cognitive Science Society, Wisconsin, USA.

Henley, N. M. (1969). A psychological study of the semantics of animal terms. *Journal of Verbal Learning and Verbal Behaviour*, **8**, 176-184.

Jaakkola, R. O. & Slaughter, V. (2002). Children's body knowledge: Understanding 'life' as a biological goal. *British Journal of Developmental Psychology*, **20**, 325–342.

Kail, R., & Nippold, M. A. (1984). Unconstrained retrieval from semantic memory. *Child Development*, **55**(3), 944-951.

Kail, R. V. (1990). *The development of memory in children*. New York: Freeman.

Keil, F. C. (1983). On the emergence of semantic and conceptual distinctions. *Journal of Experimental Psychology-General*, **112**(3), 357-385.

Lin, E.L. & Murphy, G.L. (2001). Thematic Relations in Adult Concepts. *Journal of Experimental Psychology: General,* **130**(1), 2-28.

Lucariello, J., Kyratzis, A., & Nelson, K. (1992). Taxonomic knowledge - what kind and when. *Child Development*, **63**(4), 978-998.

Mandler, J. M. (1983). Representation. In J. H. Flavell & E. M. Markman (Eds.), *Cognitive Development*(Vol. 3,). New York: Wiley.

Maridaki Kassotaki, K. (1997). Are rating-based procedures reliable for derivation of typicality judgments from children? *Behavior Research Methods Instruments & Computers*, **29**(3), 376-385.

McClelland, J. L. (1994). The organization of memory: A parallel distributed processing perspective. *Revue Neurologique*, **150**(8-9), 570-579.

Morrison, C. M., Chappell, T. D., & Ellis, A. W. (1997). Age of acquisition norms for a large set of object names and their relation to adult estimates and other variables. *Quarterly Journal of Experimental Psychology Section a-Human Experimental Psychology*, **50**(3), 528-559.

Neely, J. H. (Ed.). (1991). *Semantic priming effects in visual word recognition: A selective review of current findings and theories.* Hillsdale, N.J: Lawrence Erlbaum Associates.

Nelson, K. (1974). Variations in children's concepts by age and category. *Child Development*, **45**, 577-584.

Nelson, K. (1983). The derivation of concepts and categories from event representation. In E. K. Scholnick (Ed.), *New trends in conceptual representation: Challenges to Piaget's theory?* Hillsdale, NJ: Lawrence Erlbaum Associates.

Nelson, K., Fivush, R., Hudson, J., & Lucariello, J. (1983). Scripts and the development of memory. In M. T. H. Chi (Ed.), *Contributions to human development. Vol. 9. Trends in memory development research*. Basel: S. Karger.

Nelson, K., & Gruendel, J. M. (1981). Generalized event representations: Basic building blocks of cognitive development. In A. Brown & M. Lamb (Eds.), *Advances in Developmental Psychology*(Vol. 1,). Hillsdale, NJ: Lawrence Erlbaum Associates.

Paris, S. G., Lindauer, B. K., & Cox, G. L. (1977). The development of inferential comprehension. *Child Development*, **48**, 1728-1733.

Posnansky, C. J. (1978). Category norms for verbal items in 25 categories for children in grades 2-6. *Behavior Research Methods and Instrumentation*, **10**, 819-832.

Rumelhart, D. E., & Todd, P. M. (Eds.). (1992). *Learning and connectionist representations*. Cambridge: MA:MIT Press.

Sattath, S., & Tversky, A. (1977). Additive similarity trees. *Psychometrika*, **42**(3), 319-345.

Storm, C. (1980). The semantic structure of animal terms - a developmental-study. *International Journal of Behavioral Development*, **3**(4), 381-407.

Uyeda, K. M., & Mandler, G. (1980). Prototypicality norms for 28 semantic categories. *Behavior Research Methods and Instrumentation*, **12**, 587-595.

Table 1

Mean number of responses in category fluency tasks (standard deviations in brackets). One-way ANOVA shows a significant increase in mean number of responses with age, F-values (all significant at $p<0.01$) are given in column 5.

Category	Year 1	Year 3	Year 5	F(2, 152)
Animals	8.86 (3.02)	12.29 (4.55)	15.76 (3.99)	38.61
Body Parts	9.88 (4.20)	13.02 (5.1)	17.12 (4.53)	30.45
Clothes	8.40 (2.76)	10.99 (3.93)	12.28 (4.36)	14.94
Foods	8.08 (2.90)	11.87 (4.93)	14.28 (4.08)	29.24
Plants	3.74 (2.69)	5.51 (2.48)	7.40 (3.73)	18.62
Vehicles	5.28 (2.20)	8.26 (3.04)	9.66 (3.31)	29.97

Table 2.

Relative frequency of items in the 'animals' category named by at least 20% of the participants in each age group.

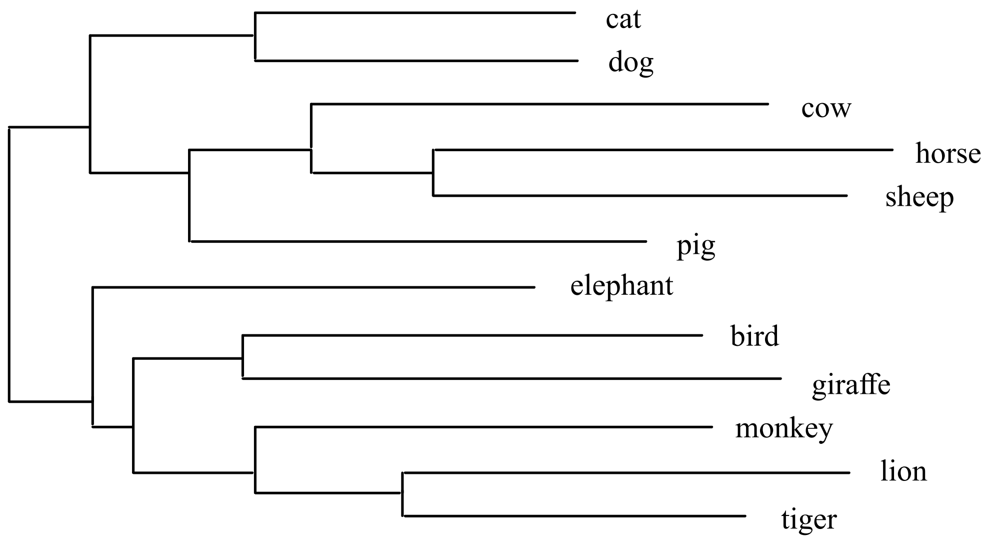
animals	***Year 1***	***animals***	***Year 3***	***animals***	***Year 5***
lion	0.48	dog	0.69	dog	0.88
tiger	0.48	cat	0.67	cat	0.86
cat	0.46	elephant	0.49	fish	0.68
dog	0.46	monkey	0.47	tiger	0.66
horse	0.44	horse	0.45	lion	0.58
pig	0.38	cow	0.42	monkey	0.52
monkey	0.34	rabbit	0.36	mouse	0.50
cow	0.32	giraffe	0.35	rabbit	0.48
elephant	0.32	lion	0.35	hamster	0.46
giraffe	0.28	pig	0.35	horse	0.46
sheep	0.28	tiger	0.33	pig	0.44
rabbit	0.22	fish	0.31	cow	0.42
bird	0.20	kangaroo	0.24	zebra	0.40
		mouse	0.24	bird	0.34
		sheep	0.24	butterfly	0.32
		dolphin	0.22	rat	0.32
		whale	0.22	sheep	0.32
		bird	0.20	fox	0.26
		hamster	0.20	elephant	0.22
		shark	0.20	giraffe	0.20
				guinea pig	0.20
				snake	0.20

Table 3.

Relative frequency of items in the 'body parts' category named by at least 20% of participants in each age group.

Body Part	***Year 1***	***Body Part***	***Year 3***	***Body Part***	***Year 5***
leg	0.78	leg	0.80	foot	0.80
head	0.62	foot	0.76	nose	0.72
eye	0.56	arm	0.65	arm	0.68
nose	0.54	eye	0.62	brain	0.68
foot	0.52	hand	0.60	eye	0.68
arm	0.50	nose	0.56	heart	0.68
mouth	0.46	mouth	0.53	leg	0.66
tummy	0.42	head	0.51	hand	0.56
hand	0.38	ear	0.44	mouth	0.56
ear	0.34	finger	0.42	finger	0.54
hair	0.32	toe	0.35	lung	0.54
neck	0.32	heart	0.31	toe	0.50
bone	0.26	brain	0.29	ear	0.48
finger	0.26	elbow	0.29	elbow	0.44
toe	0.22	hair	0.29	liver	0.40
heart	0.20	knee	0.27	head	0.38
		neck	0.27	hair	0.34
		shoulder	0.27	knee	0.34
		tummy	0.22	rib	0.34
				bone	0.28
				neck	0.28
				shoulder	0.28
				kidney	0.24
				stomach	0.24
				ankle	0.22
				skin	0.22
				back	0.20
				muscle	0.20
				thigh	0.20

Year 1



Year 3

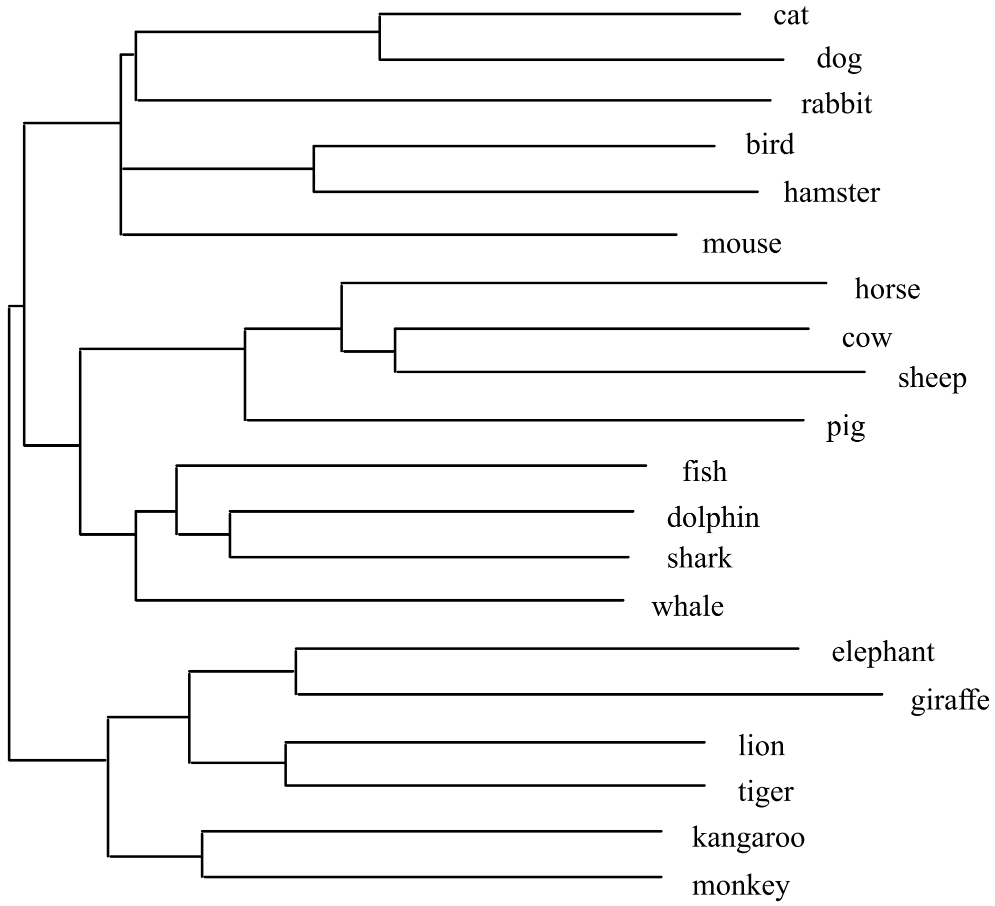


Figure 1 (part 1)

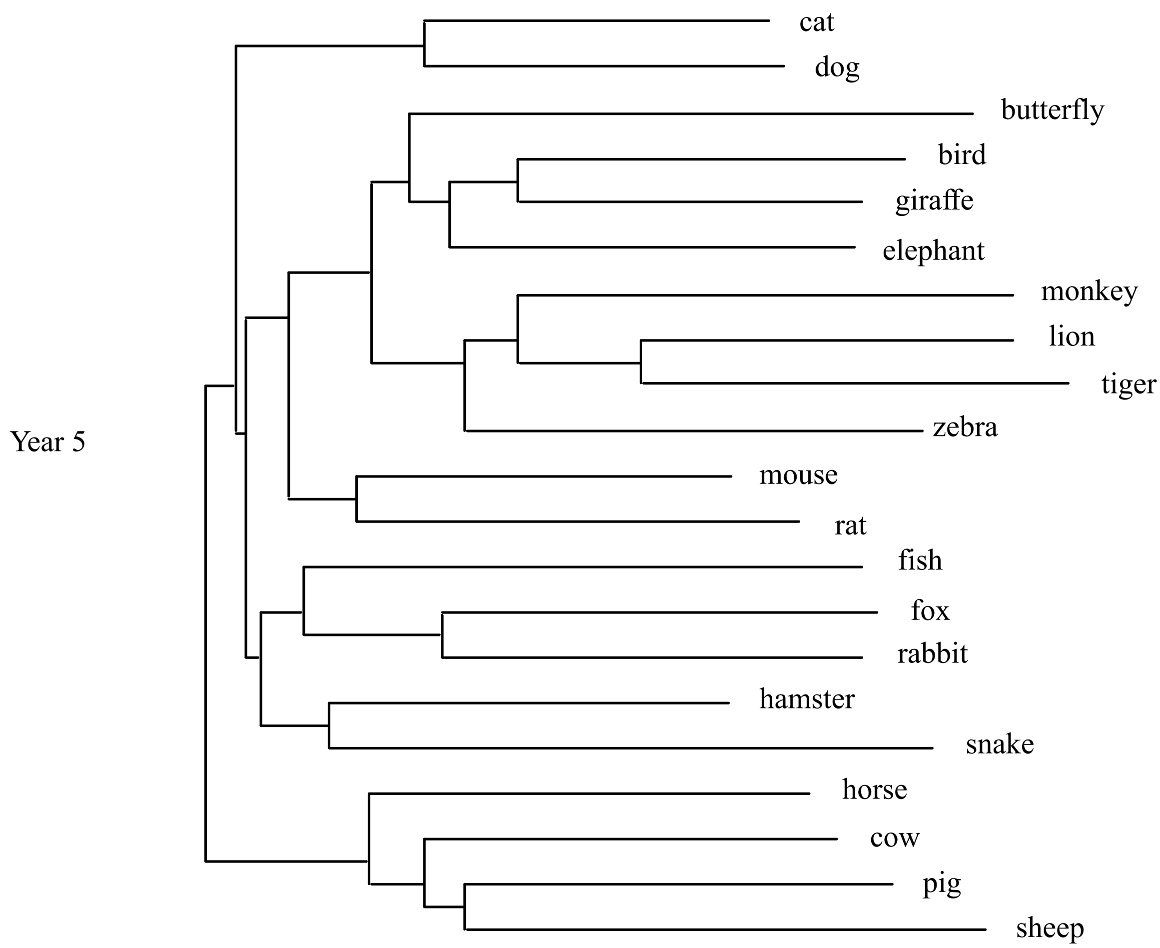


Figure 1 (part 2)

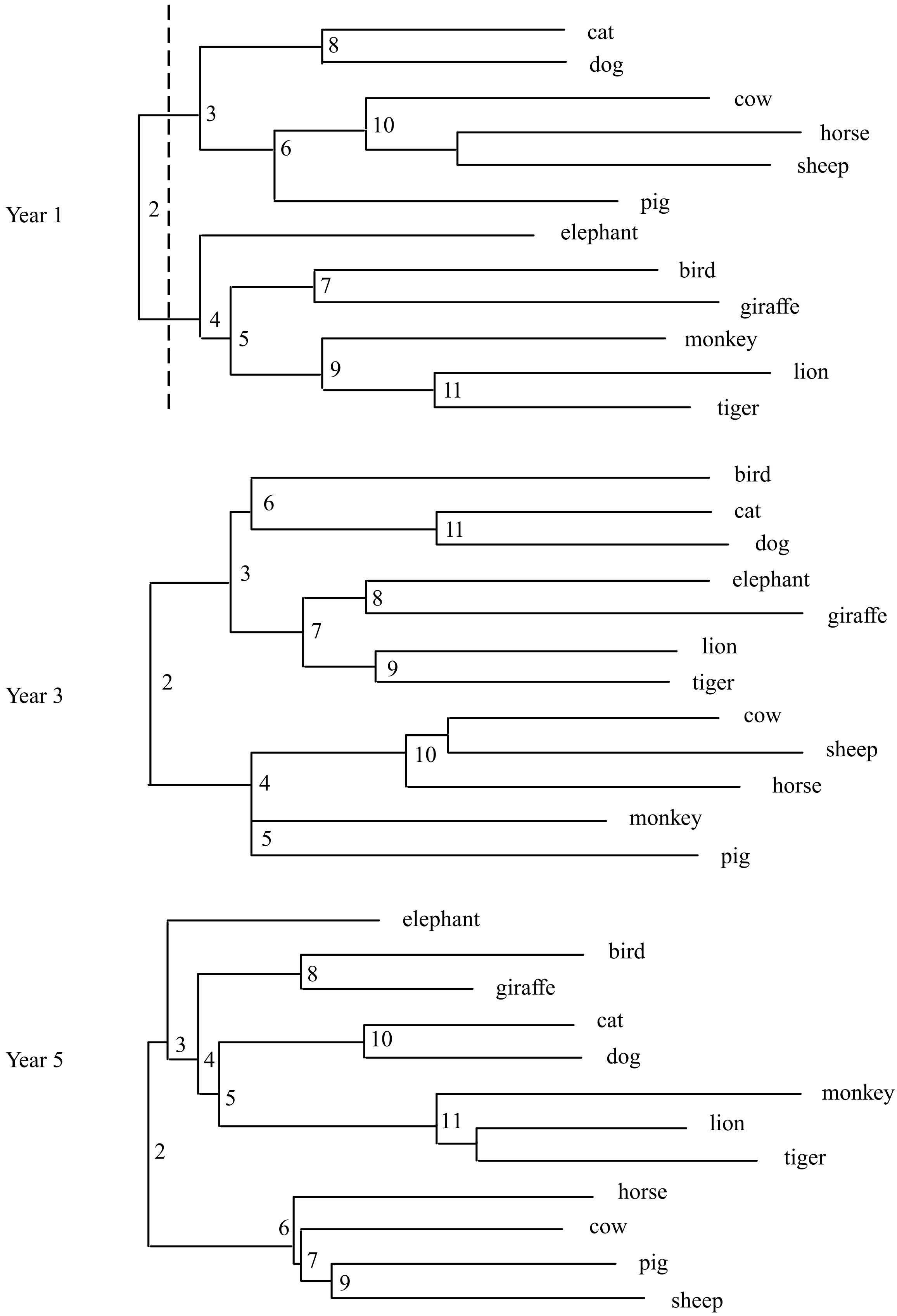


Figure 2 (part 1)

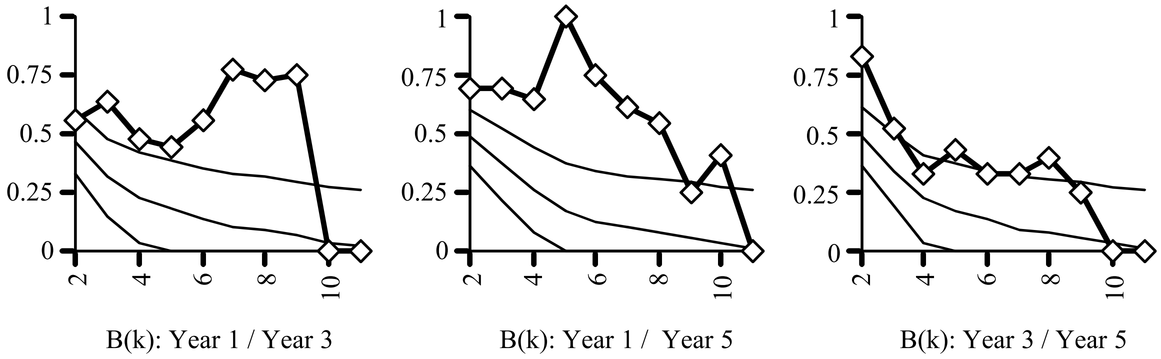


Figure 2 (part 2)

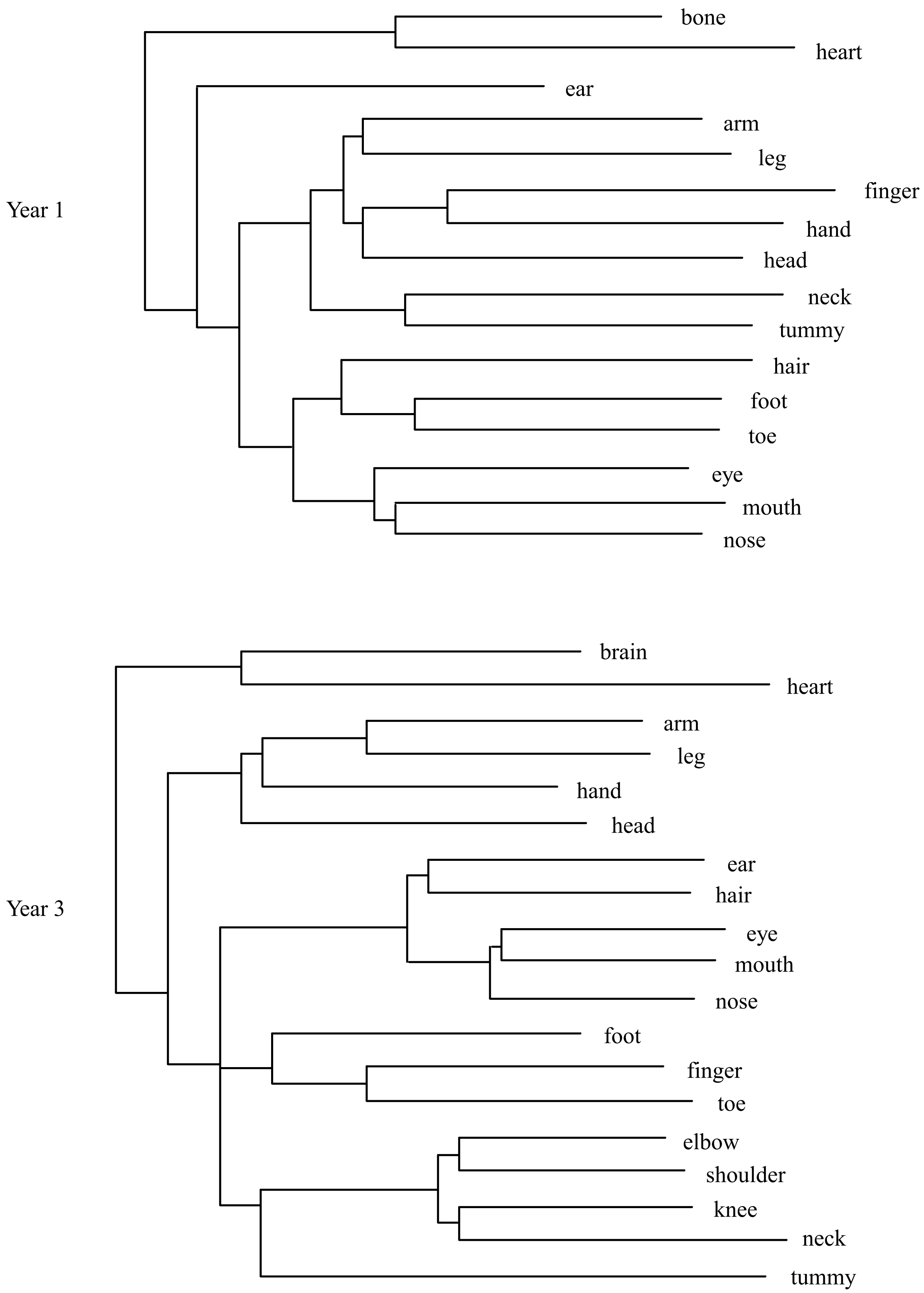


Figure 3 (part 1)

Year 5

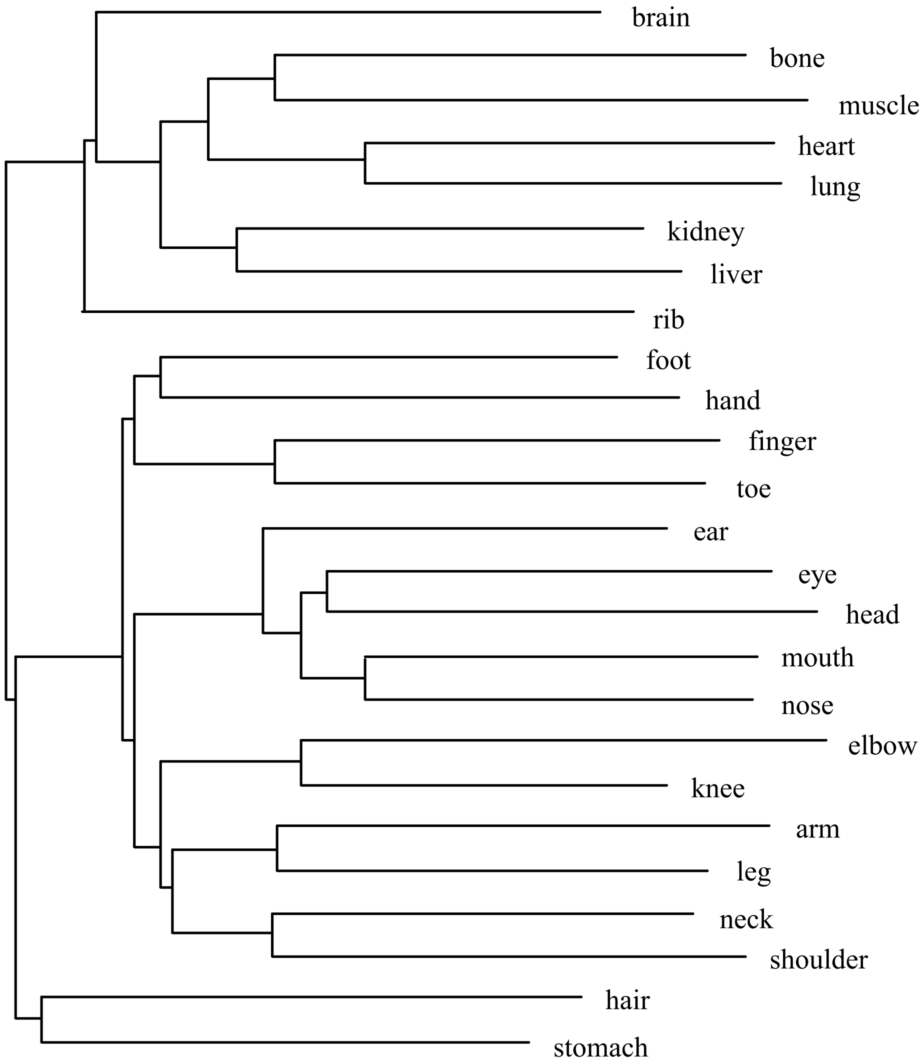
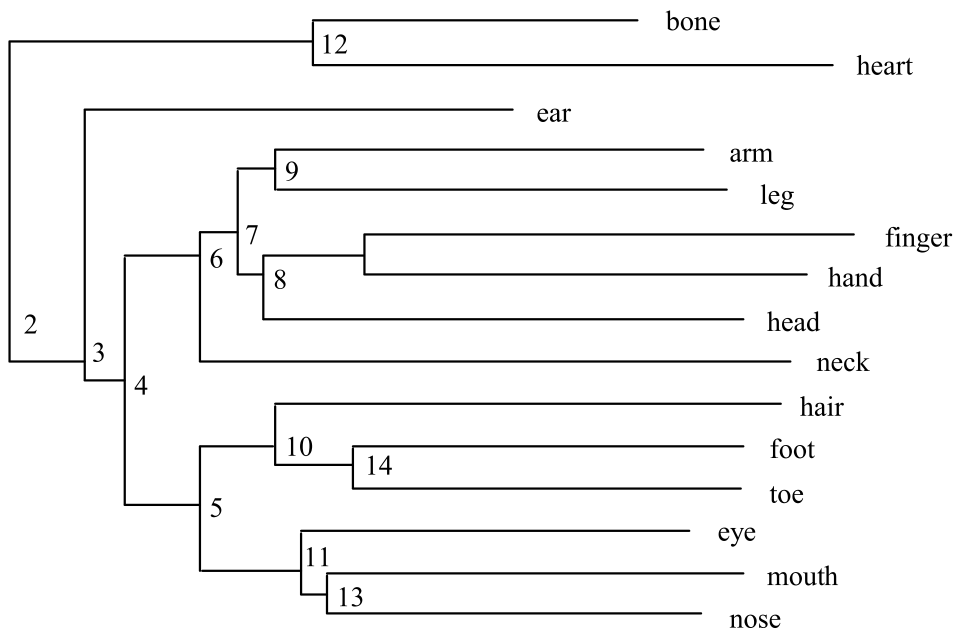


Figure 3 (part 2)

Year 1



Year 3

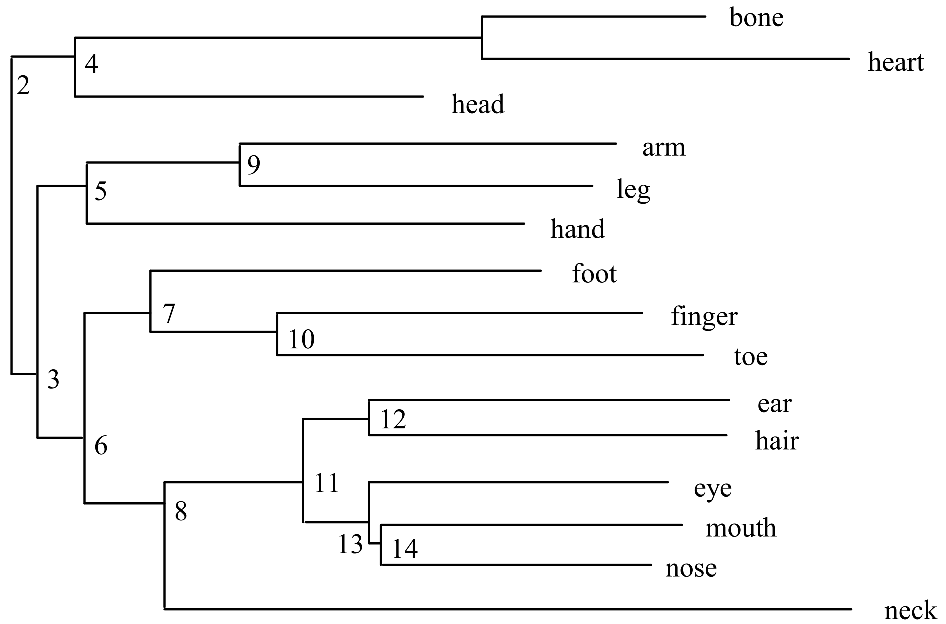
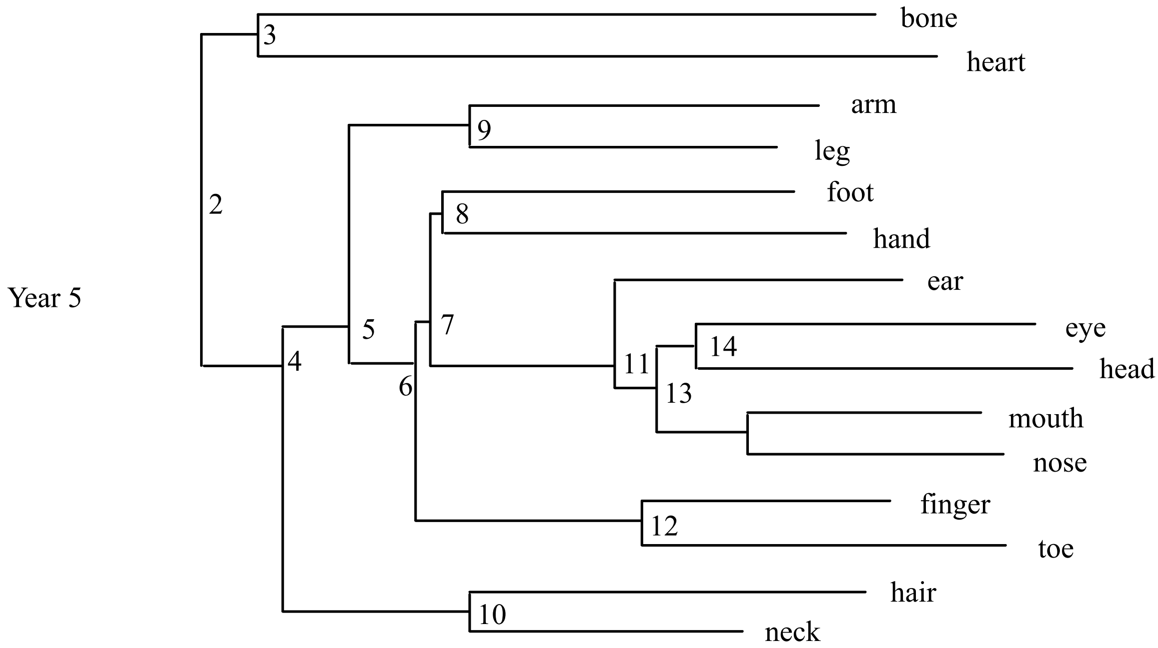


Figure 4 (part 1)



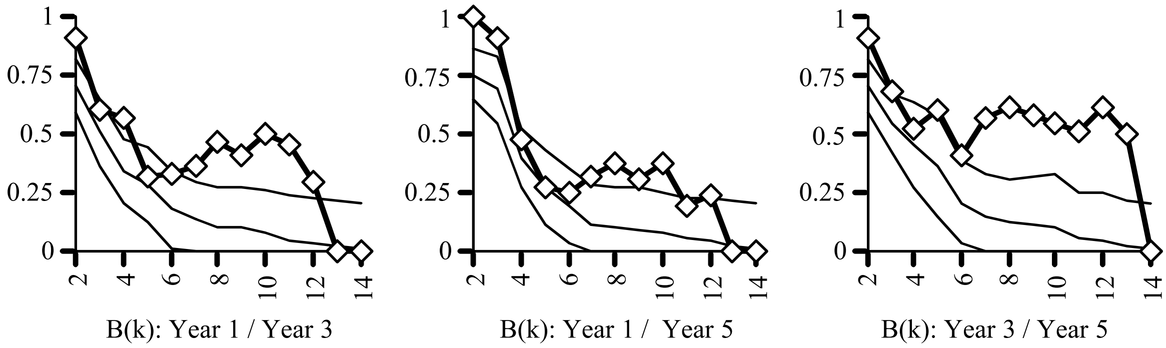


Figure 4 (part 2)

Crowe, S. J. and T. J. Prescott (2003). **Continuity and Change in the Development of Category Structure: Insights from the Semantic Fluency Task.** *International Journal of Behavioral Development, 27*, 467-479.

Erratum: On p. 470. In the equation for $\alpha(a,b)$ the parameter $\lambda(n_{al}n_{bl})$ should be a divisor not a multiplier of d_{abl}, hence the equation should read

$$\alpha(a,a) = 0, \quad \alpha(a,b) = \frac{1}{F_{ab}}\left(\sum_{l(a \in l \wedge b \in l)} d_{abl} / \lambda(n_{al}n_{bl}) \right).$$