Age of acquisition for naming and knowing: A new hypothesis.

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This paper reports an investigation into the age-of-acquisition of object names and object knowledge in a cross-sectional study of 288 children aged between 3 years 7 months and 11 years 6 months, comprising equal numbers of boys and girls. The objects belonged to four categories: animals, fruit and vegetables, implements and vehicles; and were presented in three image types: line drawings, black-and-white and coloured photographs. In the knowledge test, five probe questions were asked for each object given the spoken name. Results showed that line drawings were more difficult to name than either black-and-white photographs or coloured photographs, which did not differ. The boys significantly out-performed the girls at naming and knowing, both overall and specifically for the category of vehicles. Naming and knowledge increased steadily with age but while young children below about 6 years 6 months showed an advantage to naming, older children showed an advantage to knowing. Similarly, age of acquisition measures for each item revealed a significant shift in the relationship between naming and knowing at around 80 months. We argue that differences in learning experience lead younger and older children to associate object names with different types of information, and suggest that this difference probably accounts for the age-of-acquisition effects reported in adult object naming.

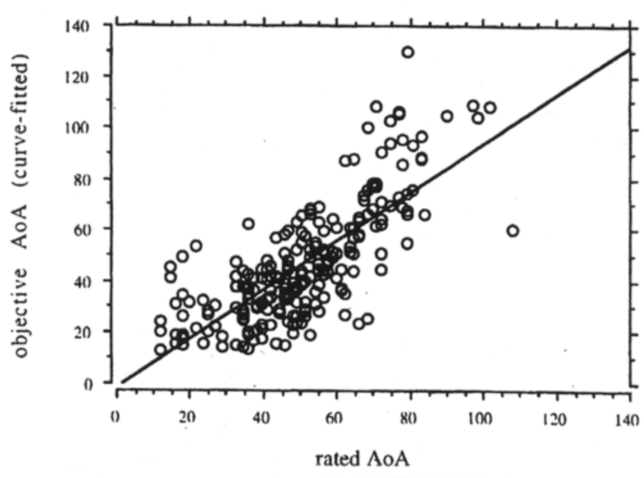
It is now well established that the age at which object names are learned predicts both the speed and accuracy with which normal adults name objects and, to a lesser extent, written words (eg Carroll and White, 1973; Gilhooly and Gilhooly, 1979; Brown and Watson, 1987; Morrison and Ellis, 1997; Hodgson and Ellis, 1998). Objects with early-acquired names are also most likely to be named by adults with naming problems (Hirsh and Ellis, 1994; Hirsh and Funnell, 1995; Nickels and Howard, 1995). Two theoretical accounts are offered for these effects of age of acquisition (AoA) upon naming. First, early-acquired words have more tightly formed phonological codes than those of later acquired words (Brown and Watson, 1987). Second, early acquired words set the shape of the developing system and so gain an advantage over later acquired words that have less influence as the system becomes increasingly inflexible (Ellis and Lambon Ralph, 2000). In consequence, later acquired items that share similar features with earlier acquired items are learned more readily than items with dissimilar features (Monaghan and Ellis, 2002).

In semantic tasks, the effects of age of acquisition have been less consistent. Using a speeded semantic categorization task ('Is this object a natural kind or an artefact?'), Morrison, Ellis and Quinlan (1992) found no effect of AoA. Nevertheless, age of acquisition effects have been reported in further studies using word-association tasks and semantic categorisation tasks (Van Loon-Vervoorn, 1989; Brysbaert, Van Wijnendaele and De Deyne,2000; Ghyselinck, 2002), and this influence of AoA in categorisation tasks has also been attributed to declining plasticity in the semantic system over time (Brysbaert et al, 2000; Ghyselinck, 2002).

Morrison et al (1992) concluded from their failure to find evidence of AoA effects in semantic tasks, that the locus of the AoA effects in naming tasks must be at the phonological level. AoA effects have, however, been reported in auditory and visual recognition tasks, where naming is not explicitly involved (Moore and Valentine, 1998; Morrison and Ellis, 1995; Brysbaert, Lange and Van Wijnendaele, 2000; Turner, Valentine and Ellis, 1998), leading Moore, Smith-Spark and Valentine (2003) to conclude that AoA effects can be found in perceptual systems as well as naming systems.

Traditionally, studies of adult naming have used measures of age of acquisition based on adult ratings. These have been found to correlate highly with a) the age at which children actually acquire object names (Morrison, Chappell and Ellis, 1997; Whalley and Metsala, 1992); b) the children's own estimates of when they learned a word (Jorm, 1991; Whalley and Metsala, 1992); and c) the age at which children can provide an adequate definition (Gilhooly and Gilhooly, 1980). However, Morrison et al (1997) found that adult ratings tended to underestimate the age at which children name some late acquired objects (see Figure 1) and they argued that either adults had failed to use the extreme ends of the rating scale, or that objects, such as 'ash tray', that adults had been frequently exposed to in childhood, now appeared less often in a child's environment. It is possible however that this discrepancy reveals a genuine difference in measurement, for it is not clear that the information that adults use when they follow the typical rating instruction to 'estimate the age at which you first learned the word in spoken or written form' is necessarily the age at which objects were first named. Adult

Figure 1. Scatterplot of the relationship between rated AoA and objective AoA for naming. Copied from Morrison, Chappell and Ellis (1997).



ratings may load more on conceptual properties, particularly in the case of later acquired objects which may not be learned through direct experience.

So far, explanations of age-of-acquisition effects have concentrated on the properties of processing mechanisms and have ignored the possibility that qualitative differences in the experience of learning object names may vary over age. Research has shown that although young children of three to five years will attend to functional information when asked to select objects on the basis of similarity (Smith, Jones and Landau, 1996), they will typically associate novel object names with the perceptual properties of the objects (Gentner, 1978; Tomikawa and Dodd, 1980; Imai, Gentner and Uchida, 1994), and particularly with object shape (Landau, Smith and Jones, 1998). Adults, by contrast, are reluctant to generalise a name on the basis of perceptual similarity and select instead to generalise names on the basis of functional knowledge. Landau et al (1998, p.2) suggest that 'the early development of object naming principally engages the perceptual systems, and only secondarily the systems of general world knowledge about objects', in which they include an object's function.

Mandler (1997) supports the view that perceptual properties are not in fact part of an object concept. In her theory, what something looks like is not the same as a summary representation (or abstract notion) of what something 'is'. Although Jackendoff (1987) also believes that knowing what an object looks like is part of knowing what an object is, he argues that the conceptual system is unable to represent the visual characteristics of objects, such as the relative sizes and shapes of objects or the relative proportions of their parts. He suggests instead that perceptual properties are represented in 3D models of the visual world, which are interpreted by conceptual structures at the categorical or specific level (see also, Miller and Johnson Laird, 1976).

Serial processing models of naming, however, generally incorporate perceptual properties of objects in the conceptual system, along with non-sensory properties such as object function (eg Ellis and Young, 1996; Caramazza, Hillis, Rapp, and Romani, 1990; Riddoch and Humphreys, 1987). Although such models incorporate an early visual processing stage in which the three-dimensional and other perceptual properties of objects are described, this perceptual knowledge is usually dedicated to the visual recognition of objects and is not considered to be part of knowing what an object 'is'.

Few group studies have compared directly the naming of objects with the knowledge held for these objects, but the findings of those that have tend to support the view that naming of familiar objects is closely associated with access to conceptual knowledge and, in particular, to the perceptual properties of object concepts. McGregor, Friedman, Reilly and Newman, 2002) found that young children provided more perceptual information for objects named correctly, than those who gave a semantically related name. Likewise, studies of adults with progressive disorders affecting naming found a relationship between the ability to recall conceptual information in definitions of an object and the ability to name the same object, with a particularly close relationship between failure to name and the loss of conceptual knowledge of the specific physical properties of the object (Hodges, Patterson, Graham and Dawson, 1996; Lambon Ralph, Graham, Patterson and Hodges, 1999).

In contrast, studies of the influence of perceptual information on the generalisation of names in early childhood stress the sensory nature of the perceptual information involved. In particular, the importance of object shape during the early stages of object naming has been argued to 'make sense' because the visual system is especially sensitive to the perception of 3-dimensional object shape (Landau et al, 1998). Evidence in favour of a direct link from early visual processing to naming has been reported by Kremin (1986; 1988), and a serial processing model has been proposed that incorporates a direct connection from 3D structural descriptions of objects to their names, bypassing access to the conceptual system (Ratcliff and Newcombe, 1982). Although receiving limited support, this model could explain the dominance of perceptual processing on early object naming and, in principle, would allow items to be named even before specific object concepts have been acquired.

The fact that adults generalise names to novel objects on the basis of function rather than visual similarity suggests that later acquired words are more likely to be associated with conceptual knowledge rather than structural descriptions. However, developmental studies of object naming typically stop at around five years and, in those studies where older children's naming has been investigated, information about object knowledge has usually not been collected (Berman, Friedman, Hamberger and Snodgrass, 1989; Cycowicz, Friedman, Rothstein and Snodgrass, 1997). Thus information about the relative development of object naming and knowledge over the latter years of the age-of acquisition range is missing.

We report here the collection of measures of the typical age at which specific objects can be named and at which objects are 'known', by which we mean that critical questions designed to tap specific perceptual and non-perceptual knowledge can be answered correctly. This 'pragmatic' definition of knowing is based on the assumption that the information derived in response to questions tapping perceptual and non-perceptual questions will result from operations within the conceptual system.

Our study used a cross-sectional design that involved 288 children aged 3years 7 months to 11 years 6 months. Since category membership has been found to influence naming accuracy in both normal adults (McKenna and Parry, 1994; Laws and Neve, 1999; Laws, 2000; Barbarotto, Laiacona, Macchi and Capitani, 2002), and in children (McKenna and Parry, 1994) we used objects selected from four categories: two categories of living things and two categories of artefacts.

Three experiments are reported. Experiment 1 investigates the children's knowledge of object properties in response to probe questions; Experiment 2 investigates the children's naming accuracy of the same objects; and Experiment 3 reports a comparison between the children's knowledge and naming using mean scores and measures of age-of-acquisition. The data analyses reveal age, gender and category differences in both naming and knowing, while comparisons across tasks reveal discrepancies between naming and knowing that change across age, suggesting the influence of different types of experience on the learning of early and later-acquired object names.

EXPERIMENT 1: OBJECT KNOWLEDGE

Three methods have been used to discover people's knowledge about objects. One is to ask for definitions; a second is to ask subjects to generate features of objects; and a further method is to ask questions about specific object properties. Definition tasks that include a detailed analysis of responses have been reported to provide a sensitive measure of semantic meaning in adults (Hodges et al, 1996), but other studies have suggested that definition tasks do not necessarily reveal all the information that adults possess about a target item (Astell and Harley, 2002; Samson, Pillon and Wild, 1998). Similarly, children's definitions have been found to include only a subset of their understanding of a word's meaning (Watson, 1995).

Probe questions and feature-generation tasks have been used with normal adults to elicit knowledge about the properties of objects belonging to different categories (Capitani, Laiacona, Barbarotto and Trivelli, 1994; Garrard, Lambon Ralph, Hodges and Patterson, 2001; McRae and Cree, 2002), and have produced rich data revealing clusters of properties associated with different categories. In our investigation, we selected to use probe questions as the method for obtaining data on which to base measures of the age of acquisition of conceptual information because, unlike other methods, answers to these questions provide uniform data with which to compare groups of children. In the same study we also collected responses to ‘What is a-?’ questions, but these data are reported elsewhere (Hughes, Woodcock and Funnell, in press).

It has been suggested that it is only when distinctive features form the core of the object concept, that objects can be accurately discriminated by children (McGregor et al, 2002). In our selection of objects, which we describe below, we endeavoured to select objects with properties that would enable them to be discriminated from other items of the same type, and to select probe questions directed towards specific properties of the object in question.

Before carrying out our main experiment, we conducted a pilot study in order to guide our final selection of objects and to test our probe questions.

PILOT STUDY

Method

Subjects

Thirty-five children (18 boys and 17 girls), attending a representative state school, took part in this study. They were selected in groups of five from each school year from Nursery (age 3 years) to Year 5 (age 10 years).

Materials

Objects were selected from four categories that captured differences in animacy, structural similarity, and manipulability: all factors that have been reported to affect object naming (Howard, Best, Bruce, and Gatehouse; 1995; Vitkovitch, Humphreys and Lloyd-Jones, 1993).

As far as possible, we chose items that have only one acceptable name, and to have names at the basic level, although what is considered to constitute the basic level is variable and can be dependent upon the level of expertise. For example, Rosch, Mervis, Gray, Johnson, and Boyes-Braem (1976) found that superordinate terms are commonly used as basic level names within certain categories, e.g. bird rather than sparrow, ship rather than liner, but Jolicoeur, Gluck and Kosslyn (1984) found that, within such categories, objects that have distinctive or atypical features are more likely to be named at the lower level, e.g. peacock rather than bird. As Jolicoeur et al. (1984) suggest, the use of generic names for such non-prototypical items would indicate that the lower level names were either not known or could not be retrieved. For this reason, we selected where necessary exemplars with distinctive characteristics, such as penguin and hovercraft.

Two categories, animals and fruits, represented living things, and two categories, implements and vehicles, represented artefacts. As far as possible, the objective age-of-acquisition norms for naming, collected by Morrison et al (1997), were used to select items across the age range. Gaps in the later acquired age ranges, which are relatively under-represented in this set, were completed with items that we judged to be appropriate for a particular age. To avoid floor and ceiling effects, we included a number of items with age of acquisition levels below and above the age range of our study. Since we planned to use the same items later for naming (see Experiment 2), we chose objects that could be pictured unambiguously. Ninety-one objects were selected: 23 animals, 22 fruits/vegetables, 24 implements, and 22 vehicles.

Within each category, up to three questions specific to each object were asked, for example ‘What does a lemon taste like?’ ‘What is it like inside?’ Questions were directed to the properties of objects that we expected to be most discriminating, and were not based on the type of information (eg perceptual or functional) which was asked for. In addition, at least four questions relevant to all objects in the category were asked. For example, the following questions were asked for all fruits and vegetables: ‘What colour is it?’, ‘What shape is it?’, ‘How do you eat it?’, ‘Where does it grow?’. Questions were designed to use colloquial language understandable to children of all ages.

Procedure

Objects were arranged into four lists of equivalent length. Each list contained objects that varied in age of acquisition and category. For each object, the probe questions followed a definitional "What is a? question (see Hughes et al, in press). The object names were presented over more than one testing session, and some younger children took up to four sessions to complete the test.

Results

The responses to the probe questions were used to determine the objects that would be appropriate for use in the following experiments. Objects were eliminated if the probe questions failed to produce responses that distinguished the target from perceptually and conceptually similar objects. Objects, such as lizards, with features (such as colour and size) that vary widely across exemplars, were also eliminated. Objects that are becoming obsolete, such as 'thimble', were removed, and objects with homonymous names, such as 'ginger', were retained only if the majority of children interpreted the object name as the target meaning. The remaining items were considered appropriate for selection in Experiment 1.

For each of the remaining objects, five probe questions were selected from the questions tested in the pilot study. We were unable to confine our selection to questions that targeted uniquely defining properties of objects, since there were simply insufficient defining properties of the objects to target. Instead, for each object, we selected two core questions that elicited distinctive features that were either unique to that object or were shared with a small number of semantic neighbours. For example, for the object 'tank', one core question referred to a virtually unique distinctive feature 'How does a tank move?' while the other core question 'What colour is a tank?' referred to a distinctive feature that could be shared with other objects of the same type; in this instance, army vehicles. Core questions were also selected to be easy for the children to answer if they knew what the object was. Three additional questions per object were selected that were shown to elicit either object-specific knowledge, for example ‘How do you get into a tank?’, or knowledge shared with semantically related objects, for example ‘What makes a tank go?’. Examples of probe questions are provided in Appendix A.

MAIN EXPERIMENT

Method

Subjects

288 children, aged between 3 years 7 months and 11 years 6 months, 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. All the children selected spoke English as a first language and none had an official statement of special educational needs. There were thirty-six children in any twelve-month age group, with three boys and three girls within every two-month age band.

Materials

Using measures of objective age-of-acquisition of naming taken from Morrison et al. (1997), together with evidence of age-of-acquisition obtained from the pilot study, we selected 18 objects for each category (72 objects in total).

To avoid floor and ceiling effects we selected three objects with names or knowledge acquired before 3 years; three objects acquired after 11 years; and three objects acquired in each of the age ranges 3 – 5 years; 5 - 7 years; 7 – 9 years and 9 – 11 years. As explained in the pilot study, five probe questions were selected for each object. Questions tapped information about perceptual, factual, functional and action features and totalled 90 questions for each category.

Table 1 presents the distribution of perceptual and non-perceptual questions across categories, with non-perceptual questions separated into those that targeted information about facts, functions or actions. Chi-square tests showed that there was no significant difference across categories between the number of perceptual and non-perceptual questions asked (chi-square, df,3 = 0.934, $p > 0.05$), but there was a highly significant difference between the number of factual, functional and action questions asked across category (chi square (df 6) = 63.79, $p < 0.001$). Numerous factual questions were asked of all categories except implements, for which questions about functions and actions predominated.

TABLE 1 ABOUT HERE

Procedure

Children were seen individually on two or three separate occasions in a quiet place at school. A brief explanation of the task was given, followed by practice items accompanied by examples of correct responses so that it was clear what kind of information was required. The practice items were referred to again during presentation of the first few test items if the child did not appear to understand what type of response to give. The 72 test objects were ranked in approximate order of acquisition and, within these ranks, objects were ordered so that no more than two objects from the same category appeared in succession.

Each object name was introduced with a general spoken question, ‘What is a - ?’ and the child’s response was noted (for a full analysis of these responses see Hughes et al, 2004). The two core questions were then asked. A question was not asked if acceptable information appropriate to the question had been included in the response to the initial general question. If the child’s responses to both core questions were clearly incorrect, questioning was discontinued for that item, and testing moved on to the next object. If one or both of the core questions was answered correctly the remaining three questions were also asked. All responses were recorded verbatim. Related, but non-target responses were prompted for all questions. For example, the response ‘fur’ to the question ‘What does a camel have on its back?’ would elicit the prompt ‘Anything else?’; and the response ‘zoo’ to the question ‘Where does it live?’ would elicit the prompt ‘Where else does it live?’ One prompt only was allowed for each question.

A child was considered to have reached his or her own ceiling for a particular category when four successive items (22% items) or a total of six items in the category (33%) failed to elicit any correct responses. At this point, no more items from that category were given. Testing continued until the child reached ceiling (or the final item) on all four categories [1].

Results

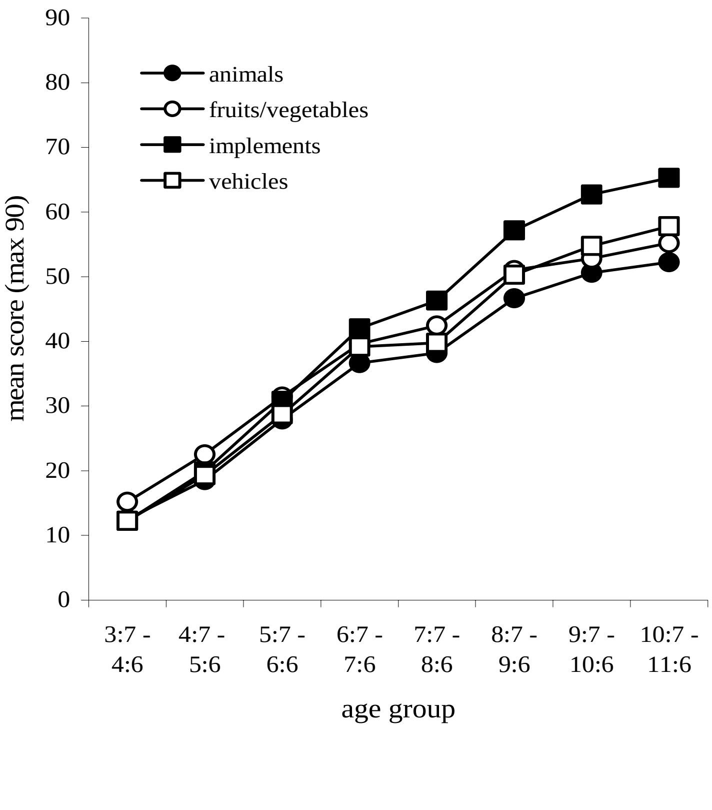
a) Scoring

Answers to questions varied in the number of pieces of information provided. Some questions elicited only one correct response, such as the answer “six legs” to the question ‘How many legs does a butterfly have?’. Other questions elicited a variety of correct responses, for example red, yellow or green were given as acceptable colours for an apple, or short descriptions, for example “It is like a flat tongue which is big and flappy” in response to the question ‘What is a beaver’s tail like?’ Descriptions were expected to include essential features in order to score a point. Scoring was lenient, so that the younger children would not be disadvantaged by a lack of vocabulary. For example, the response ‘Scrape the grass with it’, obtained at 4 years 2 months to the question ‘What do you use a rake for?’, was considered to be equivalent to a more precise response such as ‘Collecting the grass after mowing the lawn’ obtained at 11 years 2 months. Gestures were accepted as responses if these were specific and appropriate to the question. Children were given one point for each correctly answered question, amounting to a possible maximum total of five correct answers for each object and 90 for each category.

<u>b) Analyses</u>

For the purpose of these analyses, the children were divided into eight twelve-month age groups, from 3y 7m – 4y 6m to 10y 7m – 11y 6m. A mixed design ANOVA was carried out to investigate the effects of age, gender, and category. Age and gender were between-participant variables and category was the within-participant variable. Figure 2 presents the mean number of correct responses in each category over age group. There was a main effect of category, $F(3,270) = 56.22$ $p < 0.001$. Planned pair-wise comparisons (using a Bonferroni adjustment) revealed that scores for implements were significantly higher than all other categories ($p < 0.001$); scores for animals were significantly lower than all other categories ($p < 0.001$); and there was no significant difference between fruits/vegetables and vehicles ($p = .462$). There was a significant interaction between age and category, $F(21,816) = 4.62$, $p < 0.001$, in which responses to

Figure 2. Experiment: Mean number of correct responses (max. = 90) answered according to age and category.



categories became more differentiated with age, and knowledge of implements improved relative to other categories.

Figure 3. Experiment 1: Mean number of correct responses by boys and girls for all categories combined (max. = 360) and each individual category (max. = 90).

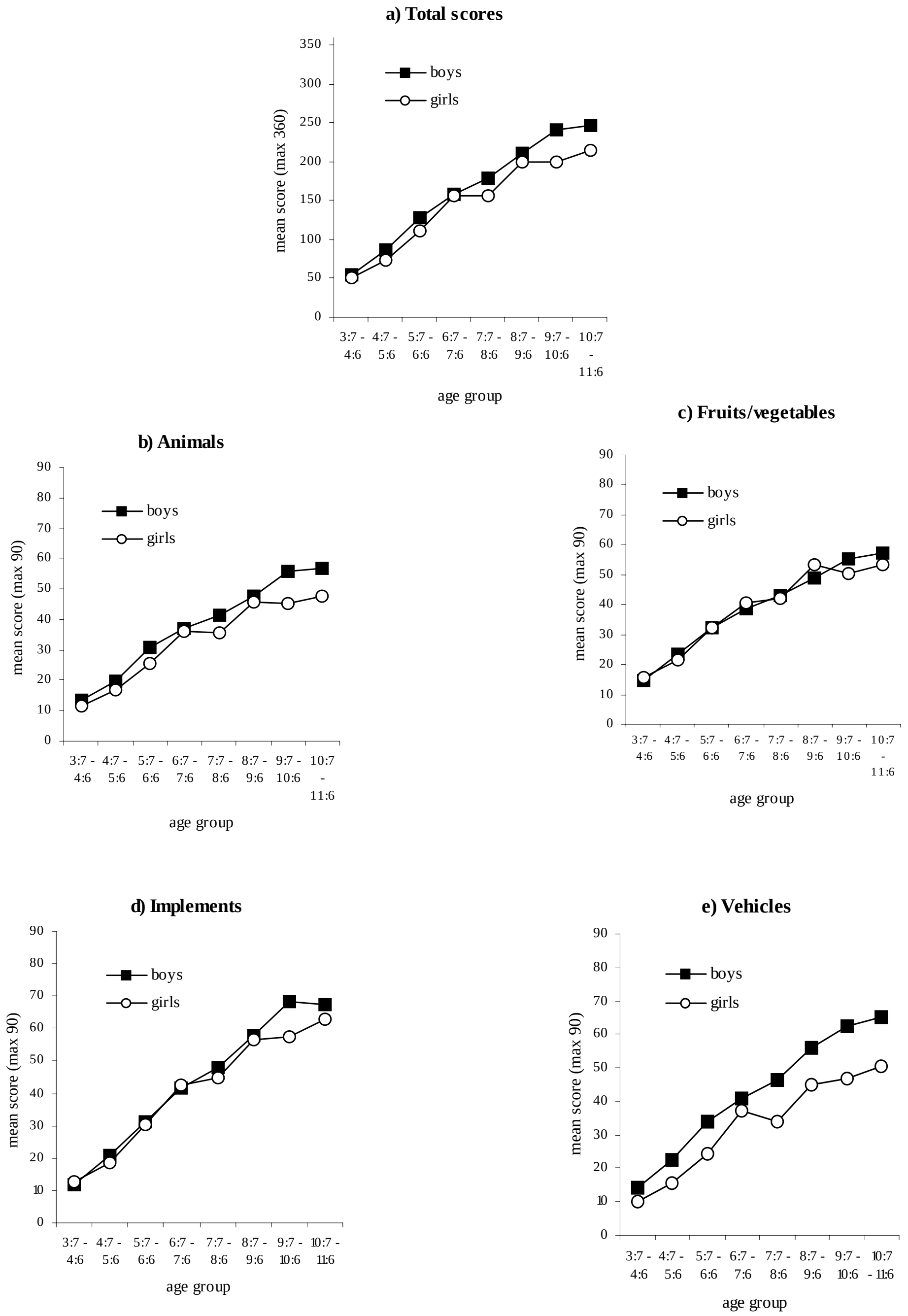
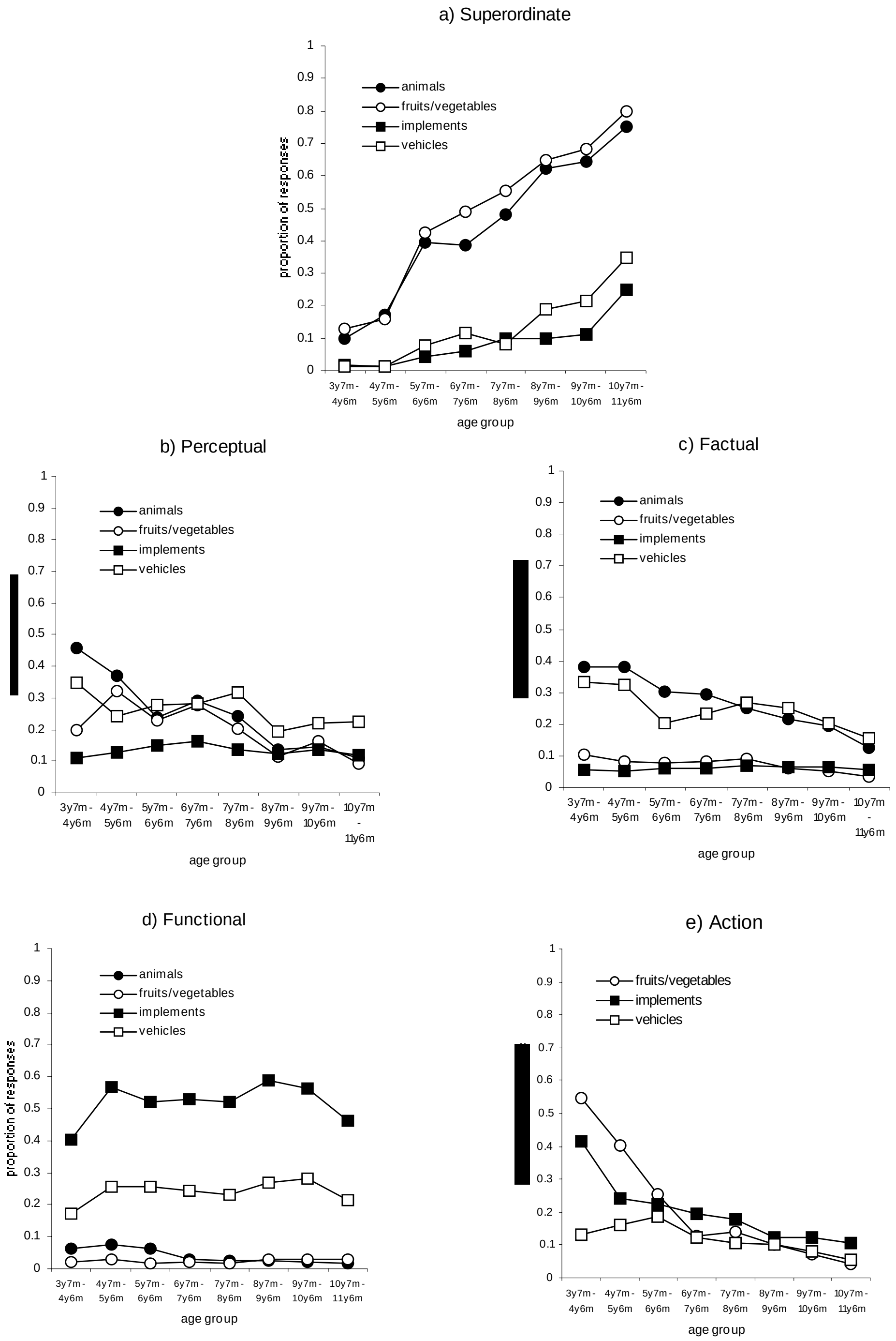


Figure 3 presents the mean number of correct responses according to gender for all four categories combined and for each category separately. There were significant main effects of age, $F(7, 272) = 80.95$, $p < 0.001$, and gender, $F(1, 272) = 12.09$, $p = 0.001$. Both boys and girls provided more information as age increased but boys consistently made more correct responses than girls. An interaction between age and gender was not significant. There was a significant gender by category interaction, $F(3,270) = 28.05$, $p <0.001$, but post-hoc *t*-tests (two-tailed, criterion for significance $p \leq 0.008$) showed that the performance of boys and girls differed significantly only for vehicles, t (279.05) = 4.12, $p < 0.001$).

A mixed design ANOVA was carried out to investigate the effects of age, and type of information accessed (perceptual or non-perceptual) on the total scores. There was a main effect of information type, $F(1, 280) = 236.8$, $p <0.001$. Planned pair-wise comparisons (using a Bonferroni adjustment) revealed that the score for perceptual questions was significantly higher than for non-perceptual questions ($p < 0.001$). There was also a significant interaction between information type and age, $F(7, 280) = 3.25$, $p < 0.05$. Figure 4 shows that the younger children answered more perceptual than non-perceptual questions correctly, and that this difference decreased with age. There was no three-way interaction between age, gender and information type.

Figure 4. Experiment 1: Mean percentages of perceptual and non-perceptual questions answered correctly.



Discussion

Overall, children knew most about implements; they had similar amounts of knowledge for vehicles and fruit/vegetables; and they knew least about animals. However the balance of knowledge about objects in each category changed across age. Levels of knowledge increased with age in all categories, but fruit/vegetables produced the most correct responses in the youngest age groups while implements emerged as the best-known category between 6y7m and 7y6m and remained at a superior level after that. These results appear to reflect the influence of personal experience, for while young children interact frequently with different types of fruits and vegetables, they become familiar with most implements only as they grow up. Even in the youngest age groups, boys knew more about vehicles than girls, and this difference increased with age, probably reflecting the boys' greater interest, and therefore exposure, to vehicles.

Perceptual questions were answered more successfully than non-perceptual questions, although this effect was more marked in the younger age groups. Interestingly, although perceptual knowledge has generally been thought to be more salient to distinctions between living things, and functional knowledge to distinctions between artefacts (Farah and McClelland (1991); Tyler, Moss, Durrant-Peatfield and Levy, 2000; Borgo and Shallice, 2001; Warrington and Shallice, 1983), the distribution of these questions, selected for their ability to discriminate between related objects, did not differ across categories (see Table 1)**.** It is noteworthy also that the distribution of these questions is similar to the distribution of different types of responses generated by the same children to the 'What is a-?' questions (Hughes et al, in press), and this convergence of evidence suggests that there is no necessary link between the type of category and the type of information that is definitive.

EXPERIMENT 2. OBJECT NAMING

Studies of visual object naming in adults and children commonly use line drawings (eg Morrison et al, 1997; Cycowicz et al., 1997; McGregor et al., 2002), but Johnson (1995) found that adding colour increased naming speed in six and eight year olds but not in ten year olds, while Barrow, Holbert and Rastatter (2000) found that the presence of colour increased the accuracy of naming of objects in the process of being acquired, but did not influence the naming of objects that were well within the children's vocabulary. Price and Humphreys (1989) found that items from 'structurally similar' categories, for example, animals and fruit, and 'structurally dissimilar' categories, for example tools and musical instruments, were named more quickly when presented as black and white photographs than as line drawings, but the 'structurally similar' categories were named even more quickly when colour was introduced. Potential interactions of this kind have not been explored in children. In this experiment, therefore, we investigated the influence of different types of image on performance.

Method

Subjects

The 288 children involved in Experiment 1 took part in this experiment.

Materials

The 72 objects presented as pictures in this experiment were those that were presented as names in Experiment 1. When the items were selected initially, care had been taken to choose objects that possess distinctive features and are named at the basic level. In some cases this involved the selection of items (eg scorpion, vulture, jetski) that are a-typical examples of their category.

The objects were presented in this experiment as coloured, black and white photographs, or line drawings. Where possible, colour photographs of the items were taken by the authors. Otherwise these were taken from the Hemera Photo Objects Premium Image Collection - Version 1.0 (Hemera Technologies Inc., 1997-1998), or donated by individuals and specialists. The images were then edited using Adobe Photoshop 5.0. All items were represented in prototypical orientation. The animals were depicted laterally (with an equal number facing left and right) apart from koala (facing forwards) and butterfly (shown from above). Vehicles were also portrayed laterally, apart from hovercraft (shown from the front). Some animals and vehicles were shown at slight angles in order to include identifying features. Implements with functional ends (e.g. hammer) were shown lengthways and others (e.g. grater) were shown so that their functional or identifying aspects were clearly visible. Fruits and vegetables were shown in their most commonly perceived position.

Images were adjusted so that they would each fit within the same sized space, and although the comparative sizes of the images were not proportional to their actual sizes, nothing was depicted in a larger size than it could appear in reality. For all categories the background to the image was removed and was replaced with a uniform pale blue. The same images were de-saturated to produce an identical set of black and white images with grey backgrounds. High quality reproductions of the colour pictures and the black and white pictures were printed on presentation paper. To produce the line drawings, the outlines of the black and white pictures were traced over, with the inclusion of enough detail to enable recognition, and presented on a grey background. Each item therefore was represented in three image types that were identical in terms of size and orientation. All three image-types were then pasted onto 15cm x 10cm cards.

Procedure

The pictured objects were divided into three sets of 24 items, with six items from each category randomly allocated to each set. Within these sets, items were presented in a mixed order of difficulty and no more than two objects from any one category appeared in succession. For logistical reasons the sets were always arranged in the same order, but the order of presentation was reversed for alternate children. Each child saw one set of 24 objects in colour, one set in black and white, and one set as line drawings, so that each child would see each item once in one of the three image conditions. Each set of objects was presented an equal number of times in each image condition, balanced across age and gender.

The experiment was carried out between two and fourteen days after the assessment of object knowledge reported in Experiment 1. Children were seen individually in a quiet place at school. All 72 pictures were presented successively in one session for all age groups. Responses were recorded in full and spontaneous self-corrections were accepted. Prompts were only provided if the initial response was a superordinate label, in which case the child was asked, "What kind of …. is it?"

Results

Each correct name was given a score of 1. Common abbreviations such as 'plane' for aeroplane, and elaborations such as 'koala bear' for koala, and the synonyms can-opener and 'tin-opener', were accepted as correct responses. Where two or more names were given for the same item only the first was scored, unless the child indicated a preferred response. If an accurate name was given following a prompt (i.e. where a superordinate label was given initially) this was scored as correct. Each child, therefore, received a total score out of 72, which was subdivided into separate scores for the different categories (out of 18) and for the different image types (out of 24). Appendix B presents the mean scores for each category and the mean total scores for the children divided into one-year age groups, with the scores of boys and girls presented together and separately.

A mixed design ANOVA was carried out to investigate the significance of the main effects and their interactions. Category and image type were within-subject factors with age and gender as between-subjects factors. For the purposes of this analysis the cohort was divided into one-year age groups. There were significant main effects of age, $F(7, 272) = 52.661$, $p < 0.001$, and gender, $F(1, 272) = 20.89$, $p < 0.001$, but no significant interaction between these factors. Boys and girls made an increasing number of correct responses as age increased and boys made more correct responses than girls across all age groups.

There was also a significant main effect of category, F(2.67, 727.18) = 49.29, $p < 0.001$. The mean scores presented in Appendix C show that, in total, animals (mean 10.42 correct) were named most accurately followed by implements (mean 10.16 correct); fruits/vegetables (mean 9.92 correct); and vehicles (mean 8.95correct). Planned pair-wise comparisons (using a Bonferroni adjustment) showed that significantly fewer vehicles were named correctly than items in any other category ($p < 0.001$ in each instance). Significantly more animals were named correctly than fruits/vegetables ($p = 0.001$) but there was no significant difference between animals and implements or between fruits/vegetables and implements. Figure 5 presents the mean scores for each category at each age level. It can be seen that the ability to name implements increases more rapidly than other categories, and this appears to be the source of the interaction.

Figure 5. Experiment 2: Mean number of correct naming responses by boys and girls, for all categories combined (max. = 72) and each individual category (max. = 18).

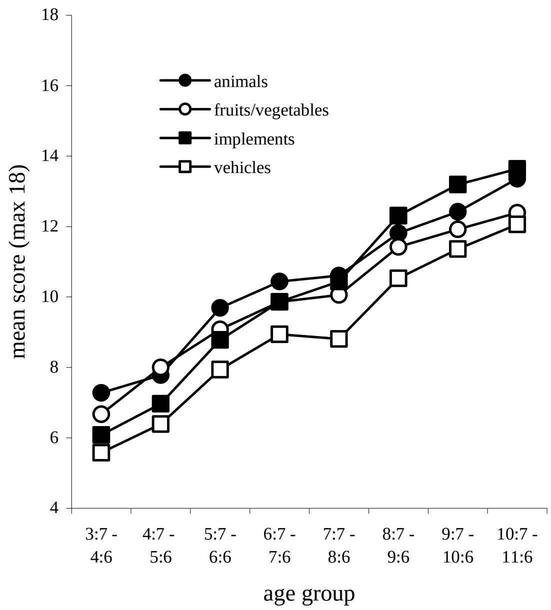
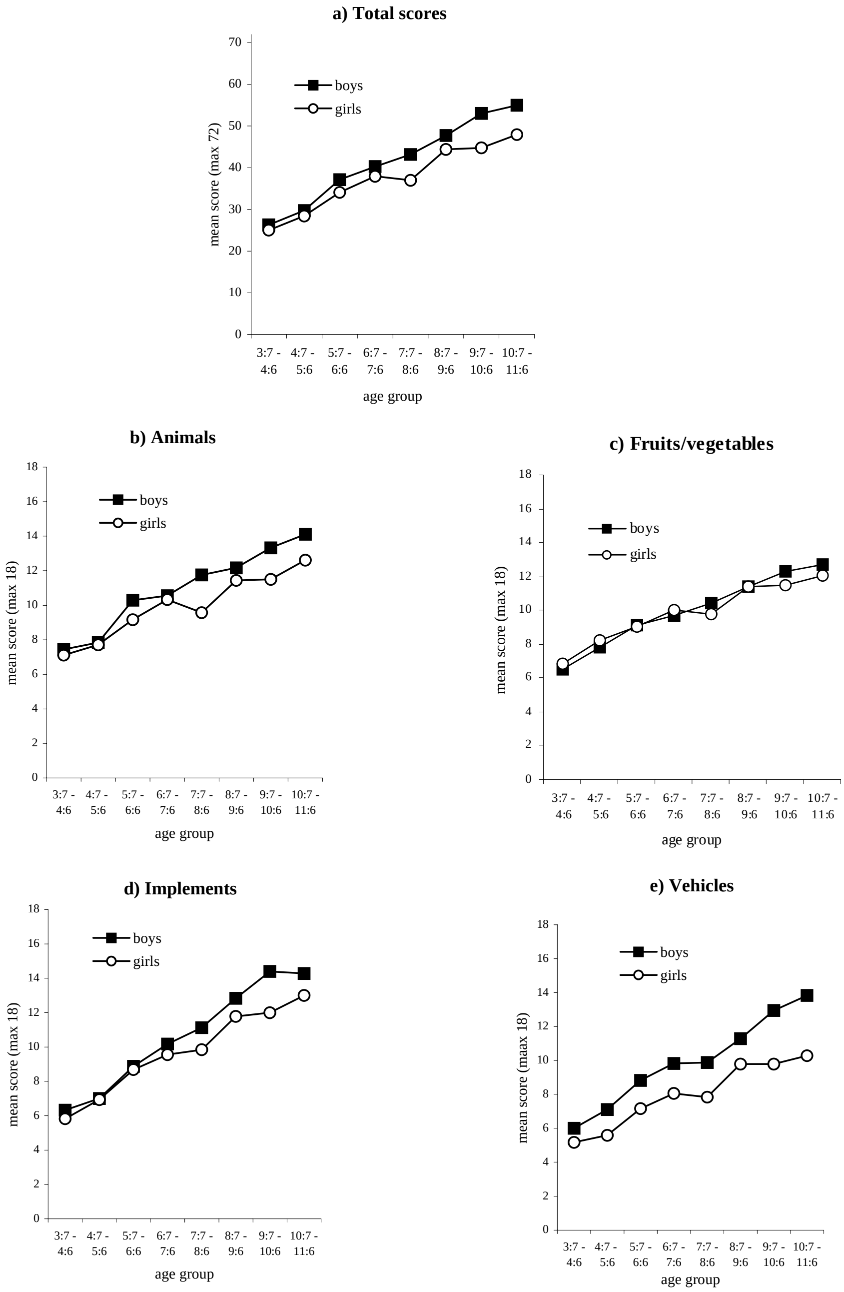


Figure 6. Experiment 2: Mean number of correct naming responses (max. = 18) by category and age group. (Note – the scale on the y axis begins at 4 rather than 0.)



There was a significant interaction between category and gender, $F(2.67, 727.18) = 17.24$, $p < 0.001$. Post-hoc t-tests (two-tailed, criterion for significance $p \leq 0.008$) showed that the performance of boys and girls was significantly different for vehicles, $t(266.25) = 5.46$, $p < 0.001$, but there were no significant gender differences for animals, fruits/vegetables and implements. As Figure 6 shows, there is a trend at all age levels for boys to make more correct responses than girls for all categories except fruits/vegetables, while for the category of vehicles the disparity becomes more marked as age increases.

There was a significant main effect of image type, $F(2, 544) = 5.43$, $p = 0.005$. Planned pair-wise comparisons (using a Bonferroni adjustment) revealed that there were significantly fewer correct responses made to line drawings (M = 12.86) compared to both black and white (M = 13.29, $p = 0.018$) and colour images (M = 13.31, $p = 0.009$). However, there was no significant difference between the black and white and colour stimuli and no significant interactions between image type and the other factors of age group, category, and gender.

Discussion

In this experiment, designed to investigate the effects of age, image type, category, and gender on the development of visual object naming, all main effects were significant, with an interaction between category and gender. Overall, children named both colour and black and white photographs more accurately than line drawings, suggesting that texture and depth assisted naming, with colour making no independent contribution. This was an overall effect with no significant differences between age groups, or categories.

Animals and implements were the best-named categories overall but, as naming accuracy in each category increased with age, the relative salience of the categories changed. While the youngest children named more items in the animal category than any other, implements became the strongest category for all age groups above 8 years 6 months, most likely reflecting increasing exposure and use of such items with age. Strong effects of gender on naming were found in which boys were significantly more accurate than girls at naming vehicles and were most accurate overall.

In general, the factors affecting the children’s naming performance bear a strong resemblance to those reported for knowing in Experiment 1. As would be expected, children's knowledge of objects and their naming accuracy both increased with age. Both tasks also showed main effects of category, although these were not identical across the two tasks. Children named animals to an equivalent level with implements, and more successfully than other categories (see Figure 5) but they possessed least knowledge overall about animals and most about implements (see Figure 3**).** Thus, relative to other categories, children's naming of animals was greater than their level of knowledge would predict. Children's naming and knowledge of implements improved steadily over age, and was the best-named category from 6 years 7 months and the best-known category from 8 years 7 months onwards. Boys significantly out-performed girls on both naming and knowing ability overall, and significantly so for the category of vehicles. Of all the categories, fruits and vegetables showed the least effect of gender.

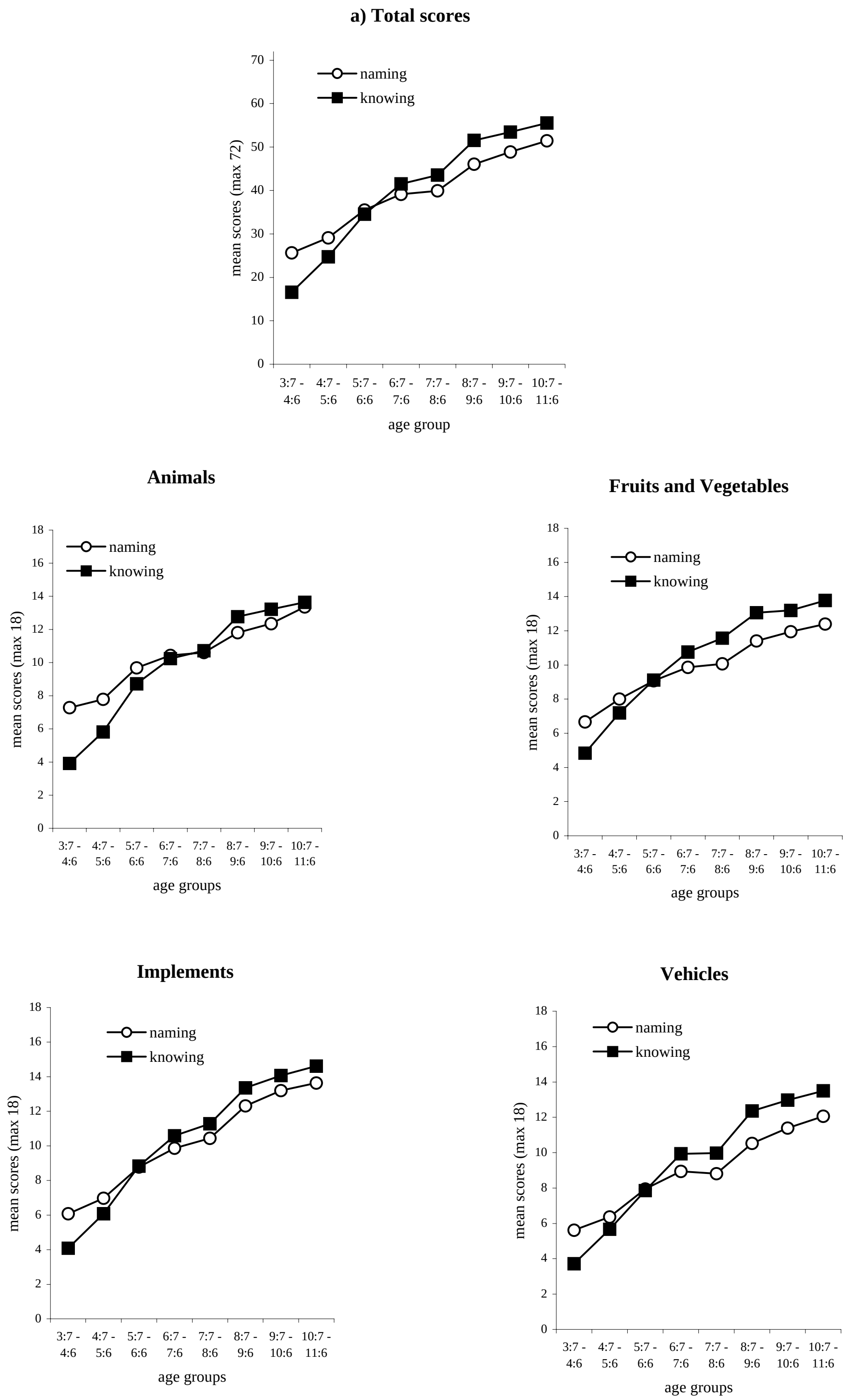
EXPERIMENT 3: COMPARISONS BETWEEN NAMING AND KNOWING

In the introduction to this paper we noted that most current theories of object naming (eg Riddoch and Humphreys, 1987; Caramazza et al, 1990) involve semantic mediation and therefore predict that knowing and naming should develop at similar rates and, where discrepancies occur, that knowing should precede naming. However, a less influential theory of naming (Ratcliff and Newcombe, 1982) proposes a direct link between structural descriptions and naming that would allow naming to proceed independently of meaning, if such a link were used. Developmental evidence has suggested that the learning of new names in young children relies more upon attention to the perceptual properties of the objects in view than upon associated real world knowledge, such as object function (Smith, Jones and Landau, 1996), raising the possibility that the younger children in our study might show an advantage for naming objects for which they appear to know little. We examine each of these possible scenarios in the following analyses. We report two comparisons, one based upon the mean scores for knowing and naming across age groups, and the second based upon derived age-of-acquisition values for naming and knowing for each object.

Mean scores for knowing and naming.

Two correctly answered questions were taken as the criterion for knowing an object. This level of knowing gave a better overall fit to the mean naming level than either one correct answer or three correct answers: the overall mean number of correctly named objects was 39.46 (sd 11.59), while the mean knowing score for one correct answer was 42.91 (sd 14.32); for two correct answers was 40.19 (sd 16.06); and for three correct answers was 34.26 (sd 18.05). Since at least one of the two core questions had to answered before the remaining questions were asked, all items reaching criterion for knowing included a correct answer to at least one core question. Interestingly, although a criterion of one correct answer produced the highest mean scores for knowing in the youngest age groups, the advantage of one correct answer compared to two correct answers diminished over age to a difference of less than two mean points in the older age groups, suggesting that if older children knew what the object was, they could give more than one correct piece of information about it. The mean scores for naming and knowing, over age groups, are presented in Figure 7 and Appendices B and C.

Figure 7. Experiment 3: Mean scores correct for naming and knowing over age for all categories combined (max. = 72) and each individual category (max. = 18).



A very high Spearman correlation of r = 0.93 (accounting for 84% of the variance) was found between the mean scores for knowing and naming over age groups with all categories combined, providing preliminary support for the view that object naming and object knowledge develop hand-in-hand. A mixed ANOVA (all categories combined) revealed a highly significant effect of age and condition (ie naming or knowing) $F(7,280) = 54.63$ $p < 0.001$, and an interaction between category and condition ($F(2.88, 280) = 28.48$ $p < 0.001$). Figure 7 reveals a changing relationship between levels of knowing and naming across age: an advantage for naming is found in young children aged between 3 years 7 months to 5 years 6 months, while an advantage for knowing is found in children older than 6 years 7 months. This shift in advantage between the ages of 5 years 6 months and 6 years 6 months is repeated in all categories except animals. For this category, young children show a more enduring advantage for naming, lasting up to 6 years 6 months, and a later advantage for knowing established by 8 years 7 months. Thus, the high correlation between knowing and naming reported above does not reflect a reliance of naming upon levels of knowing, but rather a steady increase in levels of performance in both tasks with increasing age.

The results reveal a relative independence between naming and knowing that varies with age. Young children name objects they appear to know relatively little about, while older children appear to know about objects that they are unable to name. These dissociations across age are so systematic that it seems unlikely that they arise from discrepancies in the stimuli. However, the inability of young children to answer questions about many objects that they were able to name could reflect a difficulty with expressing adequately their knowledge in words. For a number of reasons this seems unlikely. First, we were careful to use simple language in our questions and a lenient criterion for acceptable answers (eg. What are the parts of a hammer like? Child 3 years 6 months: “A long stick”). Second, some of our questions required gestures as answers, rather than words, and gestures were accepted as answers to other questions if these were specific and appropriate. Thirdly, children could fail to answer a question addressing one object (eg What colour is a penguin?) but give the required response (ie “Black and white”) to a different question (eg What colour is a cow?). Finally, the disadvantage to levels of knowing in the animal category lasted until age 6 years 7 months, when language ability is well developed. Thus, other factors apart from immature language development must account for the disparity.

In sum, comparisons between naming and knowing based on mean scores per age group suggest that early-acquired object names are associated particularly with representations of the physical properties of the object, while later-acquired names are associated particularly with conceptual knowledge.

Age-of-acquisition measures for naming and knowing of objects.

a) Naming.

Morrison et al (1997) reported the first objective age of acquisition measures of visual object naming. They tested the naming of 280 children aged 2 years 6 months to 10 years 11 months, using 297 drawings of objects, from which two objective AoA measures were derived. The first measure used logistic regression equations to calculate the age at which each item was named by 50% of the children. The second measure used a simple rule to calculate the mean age at which 75% of children named an object, based on the mean of a range of ages at which this criterion was met. The two measures correlated very highly ($r = 0.97$), and both also correlated highly with adult ratings of age of acquisition based on the written names of the same objects ($r = 0.759$ and $r = 0.747$ respectively) although, as noted earlier, when compared with the children’s naming data, there was a tendency for adults to underestimate the age at which they acquired later-acquired words.

Following Morrison et al, we analysed the children’s naming data using a logistic regression procedure to calculate the exact age, in months, at which a child first had at least a

50% probability of naming an item correctly. The independent variable was age in months (from 43 to 138) and the dependent variable was naming score (1 or 0 for each participant). The objective AoA values for naming are reported in Appendix D. Twenty-two items (six animals, six fruits/vegetables, five implements, and five vehicles) achieved probabilities of more than 50% at the earliest age level (ie at 43 months) and were given an Objective AoA value for naming of < 43 months. A further 17 items (five animals, six fruits/vegetables, three implements, and three vehicles) failed to reach the 50% level at any age, and were given an Objective AoA value for naming of > 138 months.

The logistic regression procedure was repeated with age (in months) and gender as main effects, in order to determine whether the values of objective AoA differed for boys and girls (see Appendix D). Age was always the strongest predictor of performance but gender made a significant contribution for some items. Eighteen items (9 vehicles, 2 animals and 7 implements) showed a naming advantage for boys of at least twelve months and girls failed to reach the 50% criterion for nine of these items. The only item to be named by girls earlier than boys was '<u>ruler</u>', for which there was an advantage to girls of 6 months. Only the category of fruit and vegetables failed to produce any items for which there was a discrepancy in age across gender.

When the variable of image-type was entered into the logistic regression procedure it was not a significant predictor for any individual item once age and gender had been taken into account. However, an examination of the correct responses made under each image condition revealed that for some items there was a trend for colour and/or black and white images to be named more accurately, particularly in the fruits/vegetables category (e.g. <u>lemon</u>, <u>rhubarb</u>).

<u>b) Knowing</u>

Age-of acquisition scores were generated for each subject from the data collected in Experiment 1. To check that the criterion of two answers correct, that was used earlier calculate mean scores correct, was appropriate also for age-of-acquisition measures, we calculated scores for three levels of knowing, based on one, two or three questions correctly answered. Each child was awarded a ‘knowing’ score of one or zero for every object, according to whether or not he/she had met a particular level of knowing. For each of the three levels of knowing, logistic regression was used to calculate the exact age, in months, at which a child had at least a 50% probability of demonstrating adequate knowledge of an object (cf Morrison et al, 1997). The dependent variable was the ‘knowing’ score (one or zero for each child for each object) and the independent variable was age in months (from 43 to 138).

The numbers of items that first reached the 50% criterion in a particular age group are presented as figures for each level of knowing in Appendix E. At level one, twenty-two objects obtained age of acquisition scores of less than 43 months, while at level three, just two objects reached criterion in the youngest group. Level two – one core question plus one other – appeared to best reflect the level of knowledge of the objects held by the youngest children, and this level had relatively little effect on scores in later age groups. A minimum criterion of two questions correctly answered was therefore used to derive the knowing age of acquisition scores for each object. These are reported in Appendix F**.** At this level of knowing, 8 objects (two from each category) achieved probabilities of more than 50% at the earliest age level and were given an objective age-of-acquisition value of less than 43 months (the lowest age of the children tested). A further eleven objects (three animals, four fruits/vegetables, two implements and two vehicles) did not reach the 50% level for knowing, and were given an objective age-of-acquisition value of greater than 138 months (the oldest age of child tested).

To investigate potential differences between objective AoA measures for boys and girls, the logistic regression procedure was repeated with age in months and gender as main effects (see Appendix F). In line with the analyses made in Experiment 1, age was the strongest predictor of knowing performance and, where gender differences occurred, it was always the case that boys knew about objects earlier than girls. Gender made a significant contribution to seventeen objects (five animals, two implements and ten vehicles) and, for five of these objects, the discrepancy in age of acquisition between the performance of boys and girls was greater than 24 months. No significant gender differences were found for fruits/vegetables.

Comparisons between AOA measures for naming and knowing.

Figure 8. Experiment 3: The positive relationship between age of acquisition for naming and knowing for individual objects. (Note – x denotes objects named but not known before 43 months and objects known but not named before 138 months. See text for further details.)

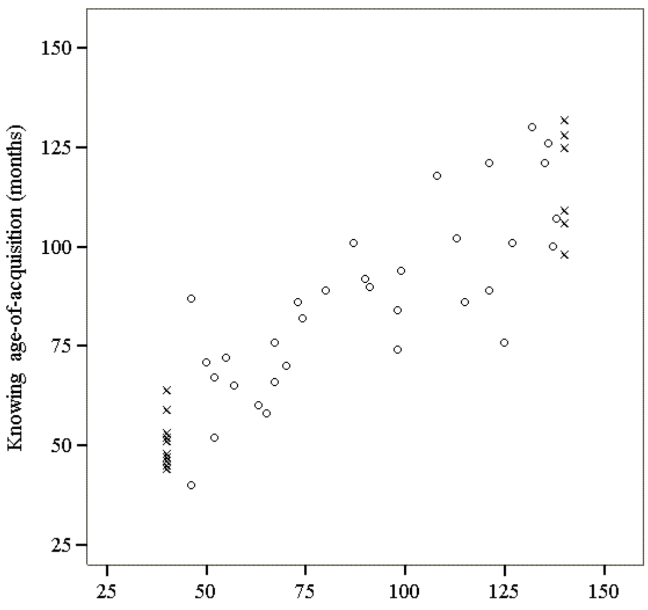


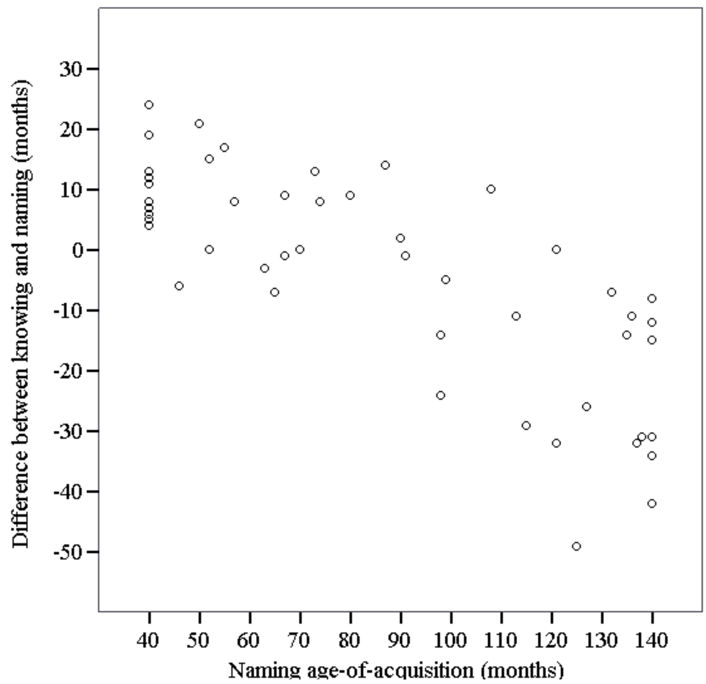
Figure 8 presents a scatter plot of the relationship between objective age of acquisition for knowing and naming for each item (obtained using logistic regression analysis, $R^2 = 0.63$)**.** The figure includes fifteen objects named before the minimum age of 43 months but known after this age, and six items known at or before the maximum age of 138 months but still un-named at this age. Omitted from this figure are seven items that reached criteria for both naming and knowing before 43 months and 11 items that failed to reach criteria for both naming or knowing by 138 months.

A discrepant pattern of performance emerges from these comparisons in which some items named by the younger children are not known until a later age, while several items known by the older children are not named until a later age, so that overall, age-of-acquisition measures for naming extend across a wider age-range than those for knowing [2]. This is a conservative estimate of the size of the discrepancy because some items given notional naming ages of <43 or >138 months will have been named, respectively, before or after these ages, stretching further the age-range for naming.

For a closer look, the discrepancies are presented in Figure 9 as a comparison between age-of acquisition values for naming and knowing plotted against objective age-of-acquisition values for naming. Positive difference scores represent an advantage for naming compared with knowing, while negative difference scores represent an advantage for knowing compared with naming. A significant negative correlation (Spearman $r = 0.73$, $p < 0.001$) obtained between these measures reflects the fact that items with names acquired before the age of 80 months are likely to be named to criterion before they reach criterion for knowing, while objects with names acquired after the age of 90 months, are more likely to have been known for some time previously. An analysis of the number of objects showing an advantage to either naming or knowing that have naming ages below or above 80 months, revealed a highly significant cross-over in scores (chi square (1) = 37.07, $p <0.001$). This eighty-month shift is roughly in line with the central tendency (84 months) in shift observed in the earlier analyses of mean scores, in which the advantage for naming below the age of about 6 years 6 months (78 months) changed to an advantage for knowing above the age of about 7 years 6 months (90 months).

Gender differences were evident for thirty-seven of the items. Boys showed an advantage in comparison to girls for 17 items in the knowing task (average AoA discrepancy 19.24 months (sd 7.81); and 19 objects in the naming task (average AoA discrepancy 19.47 months (sd 10.38). Just one object showed an advantage to girls: this item, ruler, reached naming criteria for girls six months before boys, but showed no discrepancy for knowing. Of the seventeen items showing an advantage to boys, thirteen objects showed an advantage for both naming and knowing. Six objects showed an advantage to boys only for naming and four further objects showed an advantage to boys only for knowing. It is noteworthy that the items that show an advantage to boys are generally associated with actions either as part of activities (eg spanner, parachute) or, in the case of the animals (eg scorpion, vulture), actions intrinsic to the objects. Only the passive category of fruits and vegetables failed to produce discrepancies in age of acquisition between boys and girls.

Figure 9. Experiment 3: The difference in months between ages of acquisition for naming and knowing plotted against age of acquisition for naming. (Note – positive values indicate that an object is named before it is known and negative values indicate that an object is known before it is named.)



GENERAL DISCUSSION

This study has reported the collection of a unique set of objective age-of-acquisition values and mean scores for the naming and knowing of a single set of objects. Comparisons using these measures have revealed that the ability to name visually presented objects, and to answer questions given the spoken names of the identical set of objects, develops relatively independently, and that the very high correlation obtained between performances on the two tasks reflects common increases with age. While young children's naming ability exceeded their ability to provide answers to questions about the objects, older children's knowledge of objects exceeded their ability to name the same objects. Thus, the ability to find a name for an object does not appear to depend upon access to the conceptual information that is elicited in definitions or in response to probe questions about perceptual and non-perceptual properties: a view that is at odds with most serial processing theories of object naming (Ellis and Young, 1996; Caramazza, et al, 1990; McGregor et al, 2002; Riddoch and Humphreys, 1987).

We suggest that variations in the nature of the experience in which object names are encountered are at the root of the changing relationships between naming and knowing that we have found. Smith et al (1996) note that 'The typical context in which children learn object names is one in which parents point to an object in view and label it' (p.144). It is noteworthy that, in our study, the category for which the advantage to naming was most prolonged was the category of animals, for this is the category for which people typically search for visual experience; which children are explicitly shown in picture books and visits to zoo; and in which, deprived of normal context, naming seems particularly likely to be associated with perceptual rather than associated, verbally delivered information.

Older children increasingly learn about new objects through exposure to factual knowledge expressed through written and spoken language in situations in which the object may not be present or even pictured, making it likely that, for these objects, children will lack the detailed 3D structural descriptions that are constructed when objects are seen and handled. Learning that ‘a tapir has a short flexible nose’ does not tell you about the relative proportions of the nose to the head or whether the nose is relatively fat or thin. For this type of perceptual information, and for other non-structural perceptual information, such as the exact red of a poppy or the thickness of fur of a Siamese cat, a perceptual model is required that captures precisely the properties of the object. As Johnson Laird (1983) points out, only perceptual paradigms provide an analogue of the real world. Without access to a veridical perceptual description, the identification of a visually presented animal, blessed with a short flexible nose, would have to be inferred from the learned fact that “A tapir has a short flexible nose”.

The results of this study force us to conclude that being able to demonstrate conceptual knowledge of the distinguishing properties of objects, although indicative of identification, is not necessarily sufficient to distinguish the visual form of the object from similar types. What appears to be required for accurate identification of visually presented objects is prior personal experience with objects that allow detailed perceptual-structural descriptions of the physical properties of objects to be constructed. Situations in which names accompany visual exposure to objects appear to be optimal for later visual object naming. Such a conclusion is supported by models of visual object naming that propose not only a link from perceptual structural descriptions to the conceptual system, but also direct to naming (Ratcliff and Newcombe, 1982; Kremin, 1986, 1988).

A new theory of age-of-acquisition effects in visual object naming is suggested by these data: one in which the nature of the experience at different points during childhood influences the quality of information that the children can bring to object naming tasks. We propose that the robust effects of age-of-acquisition on adult object naming arise for two reasons. First, e*arly-acquired objects are likely to be recognised more readily* in visual object naming tasks because the perceptual structural descriptions of most objects will have been constructed from visual experience. Perceptual information about later acquired objects names is increasingly likely to be learned indirectly and accompanied, if at all, by rudimentary structural descriptions that lack the detail required for speedy, precise object recognition. Second, *early-acquired objects names are retrieved more readily* in response to pictured objects because the names were learned in association with the detailed and specific visual information required for later recognition [3].

This ‘quality of experience’ theory of AoA does not refute the possibility that the names of early-acquired objects are more cohesive and therefore named more quickly than later acquired words (Brown and Watson, 1987) but it does raise questions about theories of AoA based on changes in plasticity over time. Although it could be argued that the relative decrease over age in object naming compared to knowing has arisen, not because of differences in the quality of information experienced, but because the parameters of the system, set up by the earliest items, do not fit so well with items experienced later (Ellis and Lambon Ralph, 2000; Brysbaert et al, 2000), this cannot explain the relative increase in knowing over age. Instead, the different developmental trajectories of naming and knowing, that we have found, suggest that different mechanisms are involved. In sum, we propose that changes in the quality of the learning experience are responsible for the changing relationship between knowing and naming over age, and for the reliable effects of age of acquisition on adult object naming.

Notes

1. We should have preferred to present all objects and all questions to each child, but this would have meant asking 360 questions and presenting many object names that the youngest age groups would not know. To shorten the test for the younger children and to maximise attention within all age groups, we decided to obtain a personal ceiling on each category for each child.

2. Adult ratings of age of acquisition for object names have also been shown to cover a more limited range than children's objective measures of naming (see Figure 1), suggesting that adult ratings based on the age at which a word is learned 'in written form' may be biased towards conceptual knowledge.

3. A similar account can be made for the effect of AoA on the naming of written words because dual route models of reading also incorporate a direct lexical route to naming from visual (orthographic) input. Since young children generally learn to read by naming written words aloud, early-acquired words are particularly likely to benefit from this direct association between orthographic recognition of the written word and naming.

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TABLE 1

Experiment 1. Number of perceptual and non-perceptual questions per category and further breakdown of non-perceptual questions

Category	*Perceptual*	**Non-perceptual**	**Type of non-perceptual question**		
			Factual	Functional	Action
Animals	43	47	43	4	0
Fruits/Vegetables	46	44	32	5	7
Implements	40	50	10	23	17
Vehicles	45	45	30	13	2
Total	174	186	115	45	26

APPENDIX A

Experiment 1 Knowing. Examples of probe questions.

Item	**Questions**	**Examples of correct responses**
Cow	What sound does it make?	moo; low
	What colour is it?	black; white; brown; combination of these
	What do we get from a cow?	milk; meat; leather
	What does it eat?	grass; hay
	What are its babies called?	calf/calves
Radish	What colour is it on the outside?	red; pink
	What colour is it on the inside?	white
	What sort of thing is it?	vegetable
	How can you eat it?	raw; in salads
	Where does it grow?	in/under the ground/earth/soil
Chisel	Show me how you use it.	demonstration
	What do you use it for? (action)	cutting; for sculpture
	What do you use it for? (material)	stone; wood; concrete
	What sort of thing is it?	tool
	What does it look like?	flat; sharp; like a screwdriver but flatter
Rocket	Where does it go?	space; planet; stars
	How many wheels does it have?	none
	What do you say before a rocket takes off?	blast-off; 3, 2, 1 etc; countdown
	What happens when it takes off?	fire/flames come out
	Show/tell me how it takes off?	it goes straight up; demonstration of vertical take-off

APPENDIX B

i) Experiment 2 Naming. Total mean scores correct by age (max = 72) and scores for each category (max = 18), for boys and girls combined.

Age group (years:months)	Animals	Fruits/ Vegetables	Implements	Vehicles	Total
3:7 – 4:6	*7.28* (3.15)	*6.67* (2.79)	*6.08* (1.87)	*5.58* (1.73)	*25.64* (8.04)
4:7 – 5:6	*7.78* (2.46)	*8.00* (2.62)	*6.97* (2.67)	*6.39* (2.05)	*29.11* (8.00)
5:7 – 6:6	*9.69* (2.89)	*9.08* (2.09)	*8.78* (1.91)	*7.94* (1.85)	*35.50* (7.00)
6:7 – 7:6	*10.44* (2.24)	*9.86* (1.99)	*9.86* (2.60)	*8.94* (2.37)	*39.11* (7.63)
7:7 – 8:6	*10.61* (2.79)	*10.06* (2.14)	*10.44* (2.38)	*8.81* (2.63)	*39.92* (8.40)
8:7 – 9:6	11.81 *(1.89)*	11.42 *(1.75)*	12.31 *(1.92)*	10.53 *(2.13)*	46.06 *(6.08)*
9:7 – 10:6	12.42 *(2.52)*	11.92 *(1.78)*	13.19 *(2.8)*	11.36 *(3.03)*	48.89 *(8.51)*
10:7 – 11:6	13.36 *(2.38)*	12.39 *(2.06)*	13.64 *(2.82)*	12.06 *(3.28)*	51.44 *(8.90)*
3:7 – 11:6	10.42 *(3.23)*	9.92 *(2.84)*	10.16 *(3.54)*	8.95 *(3.23)*	39.46 *(11.59)*

Note. Standard deviations are in parentheses.

ii) Experiment 2 Naming. Total mean scores correct by age (max = 72) and scores for each category (max = 18), for boys and girls separately.

Age group (years:months)	Animals	Fruits/ Vegetables	Implements	Vehicles	Total
3:7 – 4:6					
Boys	*7.44* (3.15)	*6.50* (2.48)	*6.33* (1.68)	*6.00* (2.00)	*26.28* (7.58)
Girls	*7.11* (3.23)	*6.83* (3.13)	*5.83* (2.07)	*5.17* (1.34)	*25.00* (8.65)
4:7 – 5:6					
Boys	*7.84* (2.43)	*7.79* (3.07)	*7.00* (3.30)	*7.11* (2.42)	*29.74* (9.77)
Girls	*7.71* (2.57)	*8.24* (2.08)	*6.94* (1.82)	*5.59* (1.12)	*28.41* (5.61)
5:7 – 6:6					
Boys	*10.29* (3.37)	*9.12* (1.87)	*8.88* (2.26)	*8.82* (2.16)	*37.12* (7.71)
Girls	*9.16* (2.34)	*9.05* (2.32)	*8.68* (1.60)	*7.16* (1.07)	*34.05* (6.15)
6:7 – 7:6					
Boys	*10.56* (2.01)	*9.72* (1.74)	*10.17* (2.92)	*9.83* (2.48)	*40.28* (7.92)
Girls	*10.33* (2.50)	*10.00* (2.25)	*9.56* (2.28)	*8.06* (1.92)	*37.94* (7.36)
7:7 – 8:6					
Boys	*11.76* (2.75)	*10.41* (2.21)	*11.12* (2.52)	*9.88* (2.37)	*43.18* (7.92)
Girls	*9.58* (2.46)	*9.74* (2.08)	*9.84* (2.14)	*7.84* (2.52)	*37.00* (7.90)
8:7 – 9:6					
Boys	12.17 *(1.92)*	11.44 *(1.76)*	12.83 *(1.98)*	11.28 *(1.93)*	47.72 *(5.57)*
Girls	11.44 *(1.85)*	11.39 *(1.79)*	11.78 *(1.77)*	9.78 *(2.10)*	44.39 *(6.26)*
9:7 – 10:6					
Boys	13.33 *(2.43)*	12.33 *(1.53)*	14.39 *(1.50)*	12.94 *(2.80)*	53.00 *(6.54)*
Girls	11.50 *(2.33)*	11.50 *(1.95)*	12.00 *(3.29)*	9.78 *(2.41)*	44.78 *(8.41)*
10:7 – 11:6					
Boys	14.11 *(1.88)*	12.72 *(2.22)*	14.28 *(2.78)*	13.83 *(2.83)*	54.94 *(8.17)*
Girls	12.61 *(2.64)*	12.06 *(1.89)*	13.00 *(2.79)*	10.28 *(2.72)*	47.94 *(8.36)*
3:7 – 11:6					
Boys	10.92 *(3.36)*	9.99 *(2.95)*	10.61 *(3.78)*	9.95 *(3.46)*	41.47 *(12.35)*
Girls	9.94 *(3.03)*	9.86 *(2.73)*	9.72 *(3.23)*	7.97 *(2.65)*	37.48 *(10.47)*

Note. Standard deviations are in parentheses.

APPENDIX C

i) Experiment 3 Knowing. Total mean scores correct by age (max = 72) and scores for each category (max = 18), for boys and girls combined.

Age group (years:months)	Animals	Fruits/ Vegetables	Implements	Vehicles	Total
3:7 – 4:6	*3.92* (3.15)	*4.83* (3.16)	*4.08* (2.53)	*3.72* (2.60)	*16.56* (9.83)
4:7 – 5:6	*5.81* (2.86)	*7.19* (2.88)	*6.08* (3.02)	*5.67* (2.80)	*24.75* (10.01)
5:7 – 6:6	*8.72* (3.46)	*9.11* (2.98)	*8.83* (2.01)	*7.86* (2.64)	*34.53* (9.28)
6:7 – 7:6	*10.25* (3.17)	*10.75* (2.36)	*10.58* (2.58)	*9.94* (3.03)	*41.53* (9.89)
7:7 – 8:6	*10.72* (3.33)	*11.56* (1.61)	*11.28* (2.90)	*9.97* (3.41)	*43.53* (9.81)
8:7 – 9:6	12.78 *(2.40)*	13.06 *(1.84)*	13.36 *(1.99)*	12.36 *(2.17)*	51.56 *(6.41)*
9:7 – 10:6	13.22 *(2.89)*	13.19 *(2.11)*	14.06 *(2.68)*	12.97 *(3.02)*	53.44 *(9.30)*
10:7 – 11:6	13.63 *(2.96)*	13.78 *(2.13)*	14.61 *(2.21)*	13.50 *(3.21)*	55.53 *(9.35)*
3:7 – 11:6	9.88 *(4.43)*	10.43 *(3.83)*	10.36 *(4.35)*	9.50 *(4.37)*	40.18 *(16.05)*

Note. Standard deviations are in parentheses.

ii) Experiment 3 Knowing. Total mean scores correct by age (max = 72) and scores for each category (max = 18), for boys and girls separately.

Age group (years:months)	Animals	Fruits/ Vegetables	Implements	Vehicles	Total
3:7 – 4:6					
Boys	*4.17* (2.55)	*4.67* (2.79)	*3.94* (2.24)	*4.28* (2.42)	*17.06* (8.43)
Girls	*3.67* (2.68)	*5.00* (3.56)	*4.22* (2.86)	*3.17* (2.73)	*16.06* (11.28)
4:7 – 5:6					
Boys	*6.42* (2.73)	*7.26* (3.29)	*6.11* (3.81)	*6.37* (3.29)	*26.16* (11.80)
Girls	*5.12* (2.85)	*7.12* (2.42)	*6.06* (1.89)	*4.88* (1.93)	*23.18* (7.58)
5:7 – 6:6					
Boys	*9.82* (3.81)	*9.29* (2.64)	*8.94* (2.44)	*8.82* (3.00)	*36.88* (10.11)
Girls	*7.74* (2.86)	*8.95* (3.32)	*8.74* (1.59)	*7.00* (1.97)	*32.42* (8.17)
6:7 – 7:6					
Boys	*10.56* (2.83)	*10.89* (2.52)	*10.33* (2.47)	*10.44* (3.17)	*42.22* (9.79)
Girls	*9.94* (3.52)	*10.61* (2.25)	*10.83* (2.73)	*9.44* (2.89)	*40.83* (10.22)
7:7 – 8:6					
Boys	*11.41* (3.47)	*11.65* (1.69)	*11.76* (2.70)	*11.52* (2.70)	*46.35* (9.10)
Girls	*10.11* (3.16)	*11.47* (1.58)	*10.84* (3.08)	*8.58* (3.44)	*41.00* (9.97)
8:7 – 9:6					
Boys	13.00 *(2.61)*	12.44 *(1.42)*	13.33 *(1.65)*	13.44 *(1.54)*	52.22 *(5.36)*
Girls	12.56 *(2.23)*	13.67 *(2.03)*	13.39 *(2.33)*	11.28 *(2.19)*	50.89 *(7.40)*
9:7 – 10:6					
Boys	14.11 *(2.68)*	13.72 *(2.08)*	15.06 *(1.83)*	14.44 *(2.23)*	57.33 *(7.24)*
Girls	12.33 *(2.83)*	12.67 *(2.06)*	13.06 *(3.06)*	11.50 *(3.05)*	49.56 *(9.67)*
10:7 – 11:6					
Boys	14.56 *(2.30)*	14.33 *(1.97)*	15.00 *(2.11)*	14.89 *(2.32)*	58.78 *(7.31)*
Girls	12.72 *(3.30)*	13.22 *(2.18)*	14.22 *(2.29)*	12.11 *(3.43)*	52.23 *(10.20)*
3:7 – 11:6					
Boys	10.48 *(4.47)*	10.51 *(3.89)*	10.53 *(4.55)*	10.50 *(4.45)*	42.02 *(16.47)*
Girls	9.30 *(4.33)*	10.36 *(3.78)*	10.19 *(4.12)*	8.51 *(4.07)*	38.36 *(15.47)*

Note. Standard deviations are in parentheses.

APPENDIX D

Experiment 3 Age-of-acquisition (in months) for naming individual items, boys and girls separately and combined.

Note: Items are ordered in categories by age-of-acquisition for all children. Items marked * show a gender difference

	Obj-AoA (months)		
Category/Item	Boys	Girls	*All Children*
Animals			
Butterfly	<43	<43	**<43**
Camel	<43	<43	**<43**
Cow	<43	<43	**<43**
Giraffe	<43	<43	**<43**
Penguin	<43	<43	**<43**
Squirrel	<43	<43	**<43**
Donkey	46	46	**46**
Seahorse	46	46	**46**
Koala	73	73	**73**
Ostrich	74	74	**74**
Beaver*	81	98	**90**
Scorpion*	91	124	**108**
Cheetah	115	115	**115**
Vulture*	131	>138	**>138**
Llama*	136	>138	**>138**
Armadillo	>138	>138	**>138**
Pelican	>138	>138	**>138**
Tapir	>138	>138	**>138**

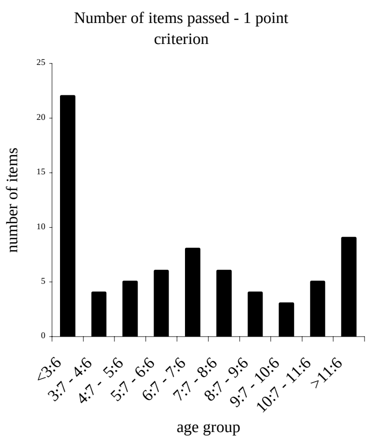
	Obj-AoA (months)		
Category/Item	Boys	Girls	*All Children*
Fruits/Vegetables			
Apple	<43	<43	**<43**
Carrot	<43	<43	**<43**
Grapes	<43	<43	**<43**
Lemon	<43	<43	**<43**
Pear	<43	<43	**<43**
Strawberry	<43	<43	**<43**
Mushroom	52	52	**52**
Tomato	52	52	**52**
Pineapple	55	55	**55**
Broccoli	63	63	**63**
Coconut	70	70	**70**
Garlic	135	135	**135**
Asparagus	>138	>138	**>138**
Aubergine	>138	>138	**>138**
Chilli	>138	>138	**>138**
Courgette	>138	>138	**>138**
Radish	>138	>138	**>138**
Rhubarb	>138	>138	**>138**

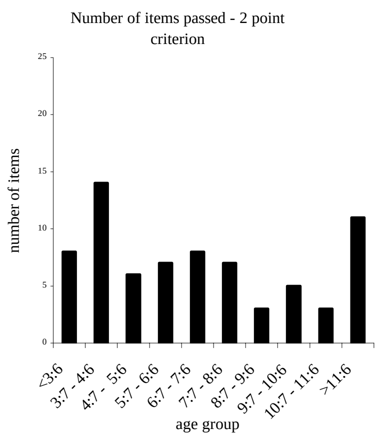
Category/Item	Obj-AoA (months)		
	Boys	Girls	*All Children*
Implements			
Camera	<43	<43	**<43**
Hammer	<43	<43	**<43**
Spoon	<43	<43	**<43**
Torch	<43	<43	**<43**
Watch	<43	<43	**<43**
Ruler*	60	54	**57**
Saw*	53	78	**65**
Binoculars*	61	74	**67**
Rake*	71	89	**80**
Grater	91	91	**91**
Can-opener	98	98	**98**
Spanner*	84	113	**99**
Whisk	113	113	**113**
Microscope*	113	130	**121**
Corkscrew	127	127	**127**
Chisel*	124	>138	**>138**
Ladle	>138	>138	**>138**
Trowel	>138	>138	**>138**

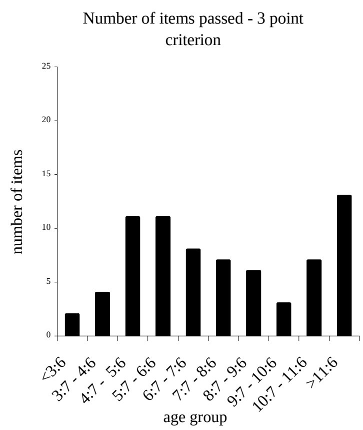
Category/Item	Obj-AoA (months)		
	Boys	Girls	*All Children*
Vehicles			
Bus	<43	<43	**<43**
Motorbike	<43	<43	**<43**
Plane	<43	<43	**<43**
Rocket	<43	<43	**<43**
Tractor	<43	<43	**<43**
Caravan	50	50	**50**
Parachute*	59	74	**67**
Tank*	67	108	**87**
Submarine*	80	115	**98**
Yacht*	111	132	**121**
Sledge	125	125	**125**
Hovercraft*	111	>138	**132**
Milk-Float*	124	>138	**136**
Jet-Ski*	119	>138	**137**
Windsurf*	126	>138	**138**
Fork-Lift*	124	>138	**>138**
Barge	>138	>138	**>138**
Tandem	>138	>138	**>138**

APPENDIX E

Experiment 3 Knowing. The number of items reaching 50% criterion in each age group according to the number of questions correctly answered.







APPENDIX F

Experiment 3 Age-of-acquisition (in months) for knowing individual items, boys and girls separately and combined.

Note: Items are ordered in categories by age-of-acquisition for all children. Items marked * show a gender difference

	Obj-AoA (months)		
Category/Item	Boys	Girls	*All Children*
Animals			
Cow	<43	<43	**<43**
Donkey	<43	<43	**<43**
Squirrel	45	45	**45**
Penguin	47	47	**47**
Butterfly	53	53	**53**
Giraffe	59	59	**59**
Camel	64	64	**64**
Ostrich	82	82	**82**
Cheetah	77	94	**86**
Koala	86	86	**86**
Seahorse	87	87	**87**
Beaver*	84	99	**92**
Vulture*	97	115	**106**
Pelican*	102	115	**109**
Scorpion*	104	131	**118**
Llama	>138	>138	**>138**
Armadillo*	134	>138	**>138**
Tapir	>138	>138	**>138**

Category/Item	Obj-AoA (months) Boys	Girls	*All Children*
Fruits/Vegetables			
Apple	<43	<43	**<43**
Carrot	<43	<43	**<43**
Pear	44	44	**44**
Grapes	47	47	**47**
Strawberry	51	51	**51**
Lemon	52	52	**52**
Tomato	52	52	**52**
Broccoli	60	60	**60**
Mushroom	67	67	**67**
Coconut	70	70	**70**
Pineapple	72	72	**72**
Chilli	98	98	**98**
Garlic	121	121	**121**
Rhubarb	125	125	**125**
Asparagus	>138	>138	**>138**
Aubergine	>138	>138	**>138**
Courgette	>138	>138	**>138**
Radish	>138	>138	**>138**

Category/Item	Obj-AoA (months) Boys	Girls	*All Children*
Implements			
Hammer	<43	<43	**<43**

Spoon	<43	<43	**<43**
Camera	45	45	**45**
Torch	47	47	**47**
Watch	47	47	**47**
Saw	58	58	**58**
Ruler	65	65	**65**
Binoculars	66	66	**66**
Can-opener	84	84	**84**
Rake	89	89	**89**
Grater	90	90	**90**
Spanner*	81	107	**94**
Corkscrew	101	101	**101**
Whisk	102	102	**102**
Microscope	121	121	**121**
Chisel*	119	138	**128**
Ladle	>138	>138	**>138**
Trowel	>138	>138	**>138**

	Obj-AoA (months)		
Category/Item	Boys	Girls	*All Children*
Vehicles			
Motorbike	<43	<43	**<43**
Tractor	<43	<43	**<43**
Bus	45	45	**45**
Plane	46	46	**46**
Rocket*	<43	55	**48**
Caravan	71	71	**71**
Submarine*	62	87	**74**
Parachute*	68	85	**76**

Sledge*	68	84	**76**
Yacht*	81	98	**89**
Jet-Ski*	93	108	**100**
Tank*	81	121	**101**
Windsurf*	98	116	**107**
Milk-Float	126	126	**126**
Hovercraft*	115	>138	**130**
Fork-Lift*	116	>138	**132**
Barge	>138	>138	**>138**
Tandem	>138	>138	**>138**