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Development of Animal Recognition: A Difference between Parts and Wholes

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A series of experiments examined children's recognition of animals by their features (Parts) and by the relative scale of the parts (Wholes). They were asked to identify the correct picture of an animal they could name from the original plus two computer-generated alternatives. We examined the developmental trends associated with upright (Studies 1 and 3) and inverted presentations (Study 3). Both experiments confirmed children's superior ability in dealing with the recognition of animal Parts over animal Wholes, especially for the younger ages tested (6- and 10-year-olds). It was not until the ages of 15–16 that children demonstrated equal performance on Whole and Part items. The late acquisition of animal Whole recognition is compared to the late acquired configural skills proposed for face recognition. © 2002 Elsevier Science (USA)

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The present article is concerned with the development of the long-term representations used in the recognition and naming of animals. It is remarkable that more is known about the representations used by infants in on-line animal categorization tasks than about those used by children and adolescents who are able to name animals. The work of Quinn, Eimas, and their colleagues has shown that surprisingly selective on-line representations of animals may be achieved by 3- to 4-month-olds (Eimas & Quinn, 1994; Eimas, Quinn, & Cowan, 1994; Mareschal, French, & Quinn, 2000; Quinn, Eimas, & Rosenkrantz, 1993). These representations may erroneously include female lions with cats but their representations are

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sufficiently articulated to exclude examples of birds, horses, tigers, dogs, and male lions. The categorization is largely achieved by representations derived from animal parts but somewhat older infants are also capable of making use of the spatial relationship between object parts (Rakison & Butterworth, 1998a, 1998b; Younger & Cohen, 1986). Less is known about the recognition abilities of older children.

There are lines of evidence concerned with recognition and naming that ought to favor representations for animals being based on the whole shape rather than their parts (Landau, Smith, & Jones, 1998; Markman, 1989; Smith & Kemler, 1977; Smith, 1989; Tversky, 1989). It has been argued that the young child does not categorize objects on the basis of the similarity of individual dimensions but on the basis of overall similarity (Smith, 1989). Perhaps in consequence, when children come to name objects they do so to the whole and not to its parts; thus, they generalize names to objects of a similar shape even if of a quite different texture, size, or function (Carey, 1978; Landau et al., 1998; Mervis, 1987). Indeed, children's acquisition of new names is largely helped by their assumption that nouns, in particular, are applied to whole objects (Markman, 1989) with the consequence that the learning of names of object parts is disadvantaged (Liittschwager & Markman, 1994).

There is also evidence from recognition studies that long-term object representations for 5-year-olds include aspects of shape (Tversky, 1989). These children were more likely to detect the missing part of an object (e.g., a car) if its exclusion affects the object's contour (e.g., a wheel rather than a headlight). Such priority of the whole object in perception is mirrored in selective attention tasks where whole (global) incoherence has a stronger effect on performance than part (local) incoherence (Navon, 1977). Indeed, young children have been found to be context dependent and unwilling to break down these displays into their constituent parts (Witkin, 1949). Nevertheless, even if affected by global shape in such displays, 4-year-old children are dominated more by parts than wholes in their similarity judgments and in copying (Dukette & Stiles, 1996; Feeney & Stiles, 1996; Stiles & Tada, 1996). Thus, even though object parts may still play an important part in adults' object recognition (Murphy, 1991; Tversky & Hemenway, 1984), they could be even more salient for the young child. A parallel can be drawn to the work on face recognition.

Two types of processing have been suggested for face recognition (Carey & Diamond, 1977; Carey, Diamond, & Woods, 1980; Lévy-Schoen, 1964). The first is based on face-part recognition (featural or piecemeal processing) and the second is based on whole-face (configural) processing. It was claimed that young school children recognize, at least, unfamiliar faces by part recognition (e.g., by their paraphernalia such as glasses and hairstyle). Older children become dominated by the whole face and, in particular, the spatial relationships between internal features within the face contour. However, there have been a substantial number of reports that have disputed the 6-year-old child's inability to make use of the whole face in recognition (Baenninger, 1994; Flin, 1985; Tanaka, Kay, Grinell, Stansfield, & Szechter, 1998). Even the effects of inversion that dramatically affect face recognition (Goldstein, 1965) are equivocal in their support of the view that young children cannot make use of the whole face (Carey & Diamond, 1994; Flin, 1985; Tanaka et al., 1998).

Carey and co-workers concluded that children's difficulties in face identification did not arise from problems at the basic level (Is it a face?) but at the subordinate level (Whose face?); perhaps, for that reason, the roles of part and whole representations have not been pursued for animal recognition. Nevertheless, our research asks questions about the recognition of animals at the basic level (Rosch et al., 1976). We restrict ourselves to questions concerning visual representations for older children and for animals that they can name correctly. Of course, our criterion of good naming will mean the exclusion of some animals. Children are not expected to have the same breadth of knowledge concerning animals as adults. Five-year-old children, for example, are not likely to be able to recognize unfamiliar animals such as an okapi; such failures at identification can easily be ascribed to limitations of experience rather than differences in processing. However, the restrictions imposed by demanding naming are outweighed by the certainty that recognition has taken place.

It is by no means clear what representations children might use for animal recognition. One prediction might be that the developing child's recognition of an animal would mirror the progression in infants for on-line categorization (Eimas et al., 1994; Younger & Cohen, 1986). Long-term representations would, in that case, develop from being part based to being based on a whole that allowed knowledge of the spatial relationship between object parts. Alternatively, the solution of the massive induction problem for naming (Markman, 1987; Quine, 1960) by use of the whole-object assumption might predict the opposite progression. So, even though children arrive at first grade being apparently able to recognize and name a large number of basic-level animals, it is worthwhile to ask whether being able to identify an animal by naming implies adult-like recognition systems.

STUDY 1

Our experiments considered school children's recognition of animals. Much previous developmental research into object recognition has been concerned with the preschool child where clear differences exist in comparison to adult recognition. There has been no previous research that has investigated the relative importance of overall shape and parts in the recognition of animals from 5 years old to adulthood. The starting point of our research is that, even for adults, correct naming of animals hides a surprising paucity of visual knowledge concerning both the whole shape and parts of animals (Davidoff & Warrington, 1999).

We examined the developmental trends associated with the identification of the correct picture of an animal from a set of three (Davidoff & Warrington, 1999). In one set (Parts), individual features had been altered while in the other set (Wholes), the overall proportions of the whole animal were changed (see Fig. 1).

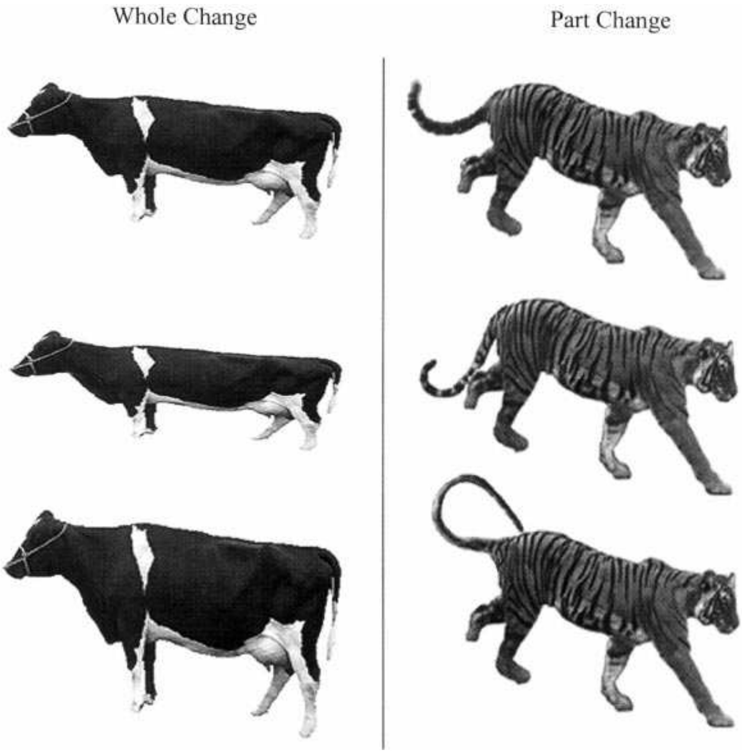

FIG. 1. Examples of Whole change and Part change. Stimuli used were colored versions.

Thus, we use a type of stimulus that has been successfully applied to the investigation of the categorical performance of infants (Rakison & Butterworth, 1998a, 1998b; Younger & Cohen, 1986). Our items have been chosen so that adults have equal difficulty recognizing which animal has the correct Part or which has the correct Whole.

Method

Participants. Three groups took part in Study 1. Thirty-seven 5- to 6-year-olds (15 females and 22 males; mean age 5 years 8 months) and 78 10- to 11-year-olds (36 females and 42 males; mean age 10 years 5 months) were drawn from Essex state schools. Twenty-four adult undergraduate controls (13 females and 11 males; mean age 20 years 7 months) were tested at Goldsmiths College, London.

Stimuli. The stimuli used in this and subsequent experiments consisted of colored items investigating animal Wholes and animal Parts (see the Appendix). They were derived from high-resolution photographs of animals taken by professional photographers and then scanned to allow digital manipulation in Photoshop. For each animal there was a correct version and two incorrect alternatives. For the Part items, the alterations consisted of the substitution of the correct part with that taken from another animal (e.g., tail or feet). For the Whole items, the alterations consisted of changes to the whole animal (e.g., proportions altered or whole body stretched or compressed). The items were chosen so that recognition accuracy for the Part and Whole items was matched for the 24 adult controls by participant [$t(23) < 1$] and by item [$t(38) = 1.137$, $p = .28$].

Procedure. The children were tested individually on colored versions of animals (see Fig. 1). The test consisted of 20 items investigating animal shape (Whole) and 20 items investigating animal Parts. Children were told that the experimenter had been playing with pictures on the computer and had altered pictures of different animals in some way. On each sheet they would see three pictures of an animal of which only one would be the correct image ("show me the one that the animal really looks like"). The task was to identify the correct item as the top, middle, or bottom image. The correct item would be equally often in all three positions.

Four practice items with feedback were given to all participants (Whole: alligator and tortoise; Part: gorilla and owl). Animals appearing as practice items did not form part of the main study. Order of presentation of the animal Part and animal Whole sets was counterbalanced.

Results and Discussion

Figure 2 shows the means and standard errors for each age group for the two sets of pictures. The performance of all age groups on each target type was significantly better than chance. The number of correct scores for each age group was analyzed in a 3 (Age: 5–6 vs 10–11 vs Adult) $\times$ 2 (Target Type: Whole vs Part) ANOVA with repeated measures over the last factor. There was a significant effect of Age [$F(2, 136) = 145.16$, $MSE = 6.07$, $p < .001$] and a significant effect of Target Type [$F(1, 136) = 48.41$, $MSE = 4.27$, $p < .001$] as well as a significant interaction [$F(2, 136) = 17.78$, $MSE = 4.27$, $p < .001$]. Post hoc Newman–Keuls pairwise comparisons revealed that, for both the Part and Whole targets, adults were significantly more accurate than 10- to 11-year-olds, who, in turn, were significantly more accurate than 5- to 6-year-olds (all $ps < .01$). More important, both 5- to 6-year-olds and 10- to 11-year-olds were significantly more accurate at Part than Whole targets (both $ps < .01$). An item analysis confirmed the superior performance on the Animal Part pictures for the 10- to 11-year-olds [$t(38) = 4.14$, $p < .001$] and the 5- to 6-year-olds [$t(38) = 1.96$, $p = .057$].

The children showed fair knowledge about Animal Parts, though, perhaps not surprisingly, less than that of adults. However, despite the two types of target being equated for difficulty for adults, both groups of children demonstrated very little knowledge about the Whole Animal. The lack of success on the Whole items is somewhat surprising. Are these Whole differences simply too subtle for children to detect? While this might seem unlikely, before continuing with further explorations of these findings, Study 2 investigated the discriminability of our stimuli.

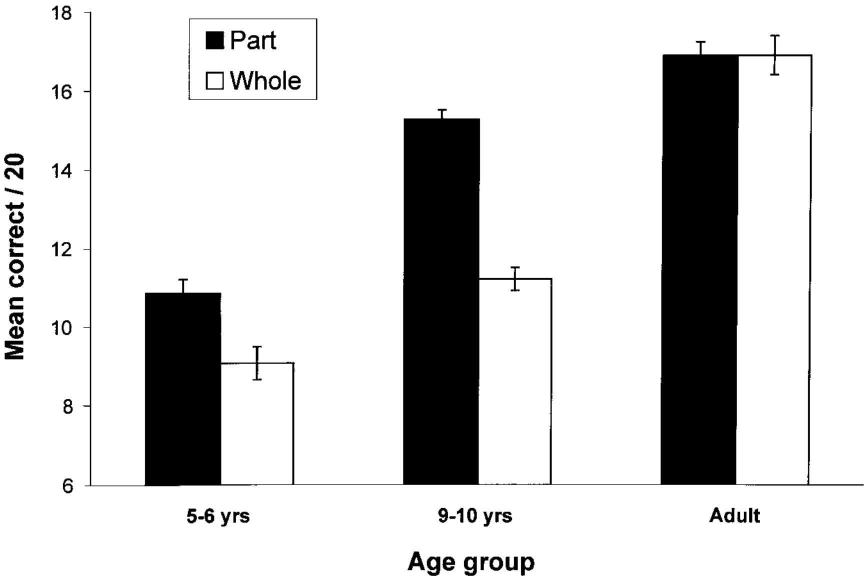

FIG. 2. Mean number (max. = 20) correct identifications in Study 1. Error bars are standard errors.

STUDY 2

Study 2 asked both children and adults to perform a simple same/different matching task when confronted with two simultaneously presented versions of the same animal. To add further evidence for the two types of stimuli being equally discriminable, we also presented the pairs of stimuli upside down. It is well known that inversion makes object recognition difficult (Rock, 1973) and is likely to encourage a perceptual matching rather than object matching strategy at short exposures.

Method

Participants. Twenty-four adult undergraduate volunteers (14 females and 10 males) with a mean age of 23 years 8 months; twenty-four 9- to 10-year-olds (13 females and 11 males) with a mean age of 9 years 8 months; and twenty-four 5- to 6-year-olds (12 females and 12 males) with a mean age of 5 years 5 months from state primary schools in Essex participated in the experiment.

Stimuli and procedure. From the images used in Study 1, we constructed 120 “same” pairs of stimuli (each of the 3 × 20 original images from each set paired with an identical image) and 240 “different” pairs (each of the 120 original images paired with each of its 2 variants). Stimuli were presented in 4 blocks (Part Upright, Part Inverted, Whole Upright, and Whole Inverted). Order of presentation of blocks was in a Latin square design. Adults saw 80 “same” and 80 “different” pairs in each condition, making a total of 320 pairs. Children were given half the number of trials in each condition.

The stimuli were presented on an Applemac laptop computer. Participants saw a fixation cross in the center of the screen for 500 ms followed by two images side by side. “Same”/“different” responses to the pair of stimuli were made with keys on the left and right of the keyboard. Half the participants made “same” responses with their right hand and half with their left. Participants were asked to respond as quickly and as accurately as possible. Trials were timed-out at 3500 ms if no response had been made.

Results

Mean reaction times were analyzed in two 3 (Age: Adult vs 9–10 vs 5–6) $\times$ 2 (Target Type: Whole vs Part) $\times$ 2 (Orientation: Upright vs Inverted) mixed-design ANOVAs; one for “same” responses and one for “different” responses.

For “same” responses there was a significant effect of Age: [$F(2, 69) = 27.51$, $MSE = 1740378$, $p < .001$] and a significant effect of Target Type (responses to Whole pairs were faster than to Part pairs) [$F(1, 69) = 8.39$, $MSE = 488082$, $p = .005$], but no significant effect of Orientation [$F(1, 69) = 1.09$]. In addition, there was a significant interaction between Age and Target Type [$F(2, 69) = 5.79$, $MSE = 488082$, $p = .005$], but no other significant two-way interactions and no significant three-way interaction. Newman–Keuls pairwise comparisons of the significant two-way interaction showed that, while there was no significant differences in response times for adults and 5- to 6-year-olds between Whole and Part pairs, 9- to 10-year-olds responded significantly faster ($p < .05$) to Whole than to Part pairs (see Fig. 3a).

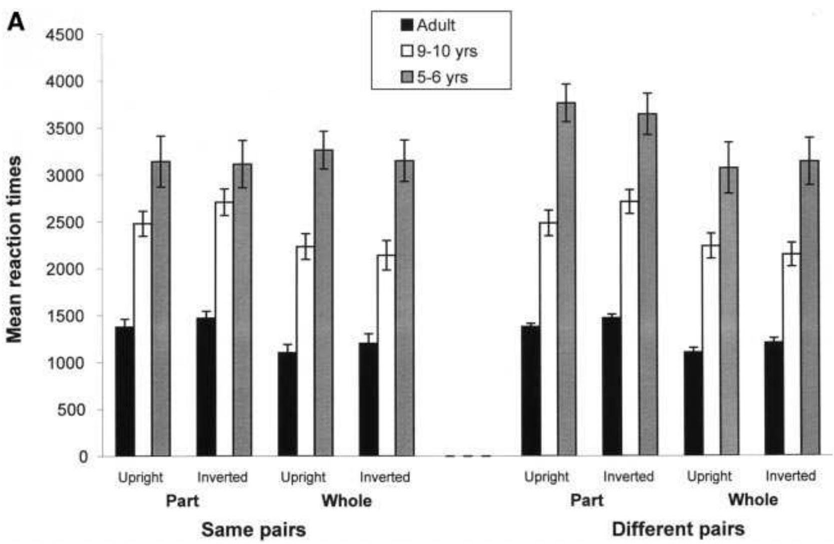

FIG. 3a. Mean latency (in milliseconds) for correct same and different decisions in Study 2. Error bars are standard errors.

For “different” responses there was a significant effect of Age: [$F(2, 69) = 37.53$, $MSE = 2837690$, $p < .001$] and a significant effect of Target Type (responses to Whole pairs were faster than to Part pairs) [$F(2, 69) = 20.65$, $MSE = 634711$, $p < .001$], but no significant effect of Orientation [$F(1, 69) < 1$]. There were no significant interactions.

Mean correct responses were analyzed in two 3 (Age: Adult vs 9–10 vs 5–6) $\times$ 2 (Target Type: Whole vs Part) $\times$ 2 (Orientation: Upright vs Inverted) mixed-design ANOVAs, one for “same” responses and one for “different” responses. Mean accuracies (max. = 20) are illustrated in Fig. 3b.

For “same” judgments there was a significant effect of Age [$F(2, 69) = 29.14$, $MSE = 12.62$, $p < .001$], Target Type [$F(1, 69) = 3.39$, $MSE = 3.45$, $p = .041$], and Orientation [$F(1, 69) = 16.84$, $MSE = 2.15$, $p < .001$]. In addition, there was a significant interaction between Age and Target Type [$F(2, 69) = 3.43$, $MSE = 3.45$, $p = .037$] and a significant interaction between Age and Orientation [$F(2, 69) = 3.81$, $MSE = 2.15$, $p = .027$], but no other significant two-way interaction and no significant three-way interaction. Newman–Keuls pairwise comparisons showed that while Whole pairs were identified significantly more accurately than Part pairs by both groups of children ($p < .01$), there was no significant difference between target types for adults. Furthermore, the Adults were the only group that were more accurate ($p < .01$) in the Upright compared to the Inverted condition.

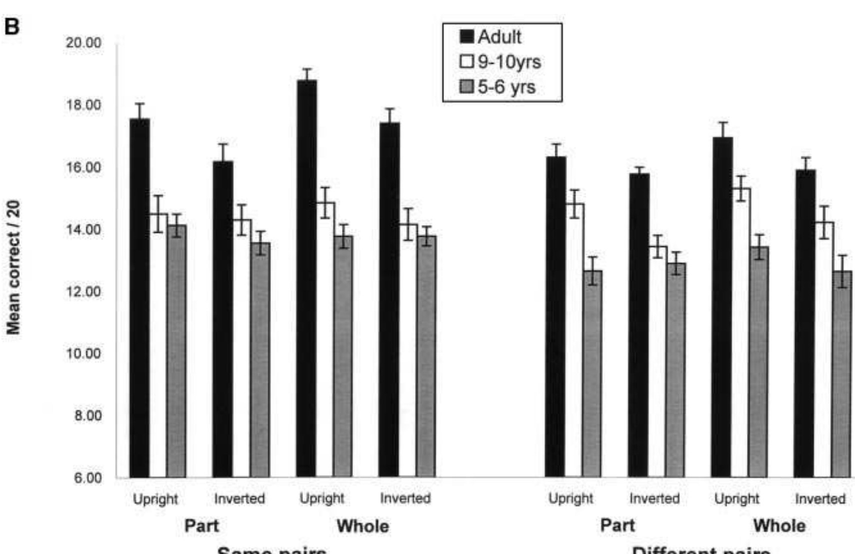

FIG. 3b. Mean accuracy (max. = 20) for same and different decisions in Study 2. Error bars are standard errors.

For “different” judgments there was a significant effect of Age [$F(2, 69) = 43.90$, $MSE = 5.76$, $p < .001$] and a significant effect of Orientation [$F(1, 69) = 8.0$, $MSE = 4.50$, $p = .006$]. There were no significant interactions.

Discussion

Study 2 investigated the discriminability of the items used in Study 1. Even under time constraints, where both adults and children were prone to error, no evidence was obtained for Whole discriminations to be more perceptually difficult than Part discriminations. Indeed, for “same” judgments, the children found the Whole pairs easier to discriminate, whereas the adults did not. Thus, there can be no concern that children’s superior performance with Part stimuli is due to their being more discriminable than Whole stimuli.

Improvement in almost any task between the ages of 5 and 11 years is to be expected. So, an important aspect of our data from Study 1 (see also Carey et al., 1980) was to show that the development occurred at different rates for the two types of stimuli. Carey et al. argued for a maturational change underlying face recognition but for which they admitted that the respective information processing skills were unknown. Study 1 suggests to some extent that difficulties in dealing with spatial relations between parts are not specific to faces. In order to further examine the processing skills and representations that contribute toward the children’s performance, the next study presented the animal stimuli either upright or inverted.

STUDY 3

In considering the development of face recognition, Carey and Diamond (1977) proposed that around the age of 10 years children change from identifying faces by parts to identifying faces from the relationship between internal parts (configural processing). The indication of configural processing used by Carey and Diamond (1977) was the impairment of performance when the face is inverted. For objects whose representations are reliably coded for top and bottom, inversion dramatically affects recognition because of the disruption to the spatial relations between parts. The disruption may apply more to those objects with internal parts for which the requirement for configural processing is more certain (Yin, 1969). However, even if inversion is more harmful to face recognition, it is damaging for many classes of stimuli, including those without internal features (Bruyer & Crispeels, 1992; de Gelder, Bachoud-Lévi, & Degos, 1998; Diamond & Carey, 1986; McLaren, 1997; Rock, 1973).

Adults show a marked difficulty in the recognition of faces from inverted stimuli. However, young children’s performance on face recognition tasks is relatively unaffected by inversion (Carey & Diamond, 1977; Goldstein, 1965). In Study 3, we ask whether the same applies to the recognition of upright and inverted Part and Whole stimuli from 10 years of age through adolescence. Our choice to start our investigation at that age was motivated by pilot studies that found younger children were unwilling to respond to the questions from inverted stimuli and, indeed, were in many cases unable to recognize the animals. From the results of face recognition studies (Carey & Diamond, 1977; Tanaka et al., 1998) it was predicted that the comparison of animal Parts would be little affected by inversion, whereas the comparison of Whole stimuli would be markedly affected by inversion.

Method

Participants. Five groups were used in Study 3, all consisting of 24 participants. The groups were adult undergraduate volunteers (14 females and 10 males; mean age 23 years 2 months), 9- to 10-year-olds (13 females and 11 males; mean age 9 years 7 months), 11- to 12-year-olds (12 females and 12 males; mean age 11 years 4 months), 13- to 14-year-olds (13 females and 11 males; mean age 13 years 4 months), and 15- to 16-year-olds (12 females and 12 males; mean age 15 years 6 months). All children were volunteers recruited from the same area as in the previous studies but none had taken part in Studies 1 and 2.

Stimuli and procedure. The same animal Part and animal Whole pictures were used as in Study 1 but these were divided into two half-sets. Half the participants saw the first half-set of pictures upright and the second half-set inverted while the other half saw the first half-set inverted and the second half-set upright. Order of presentation of the two half-sets was counterbalanced as was the order of presentation of Whole and Part items and the order of presentation of upright and inverted pictures. Instructions were identical to those in Study 1 except that participants were told that they would see some of the pictures upright and some inverted. The pictures were presented vertically in front of the participant by the Experimenter (DR). Participants were instructed not to attempt to rotate their head to see the inverted pictures. They were asked to name the animal; none ever failed to do this. The participants were then asked to point to the correct image.

Results

Correct scores were entered into a 5 (Age: Adult vs 15–16 vs 13–14 vs 11–12 vs 9–10) $\times$ 2 (Target Type: Whole vs Part) $\times$ 2 (Orientation: Upright vs Inverted) ANOVA. All main effects were significant. There was an effect of Age [$F(4, 115) = 19.28$, $MSE = 2.19$, $p < .001$], Target Type [$F(1, 115) = 79.5$, $MSE = 1.5$, $p < .001$], and Orientation. [$F(1, 115) = 49.54$, $MSE = 1.76$, $p < .001$]. In addition, there was a significant interaction between Age and Target Type [$F(4, 115) = 5.94$, $MSE = 1.53$, $p < .001$] and a strong trend in the three-way interaction [$F(4, 115) = 2.36$, $MSE, = 1.54$, $p = .057$]. The three-way interaction (see Fig. 4) was considered further by conducting separate ANOVAs on Upright and Inverted stimuli.

For the Upright stimuli, both main effects and the interaction between Age and Target Type were significant (all $ps < .001$). Considering the difference between the two Target Types at each age range by Newman–Keuls pairwise comparisons, there was no difference in performance level for adults and the 15- to 16-year-

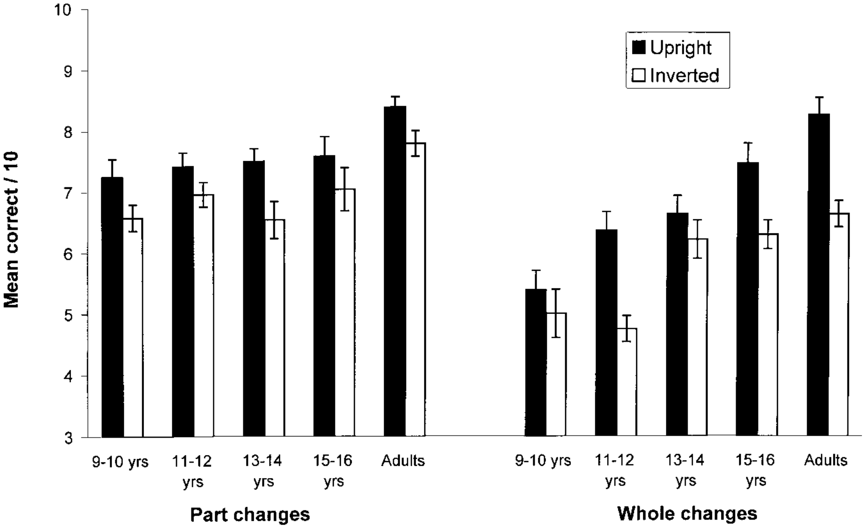

FIG. 4. Mean number (max. = 12) correct identifications in upright and inverted conditions of Study 3. Error bars are standard errors.

olds; however, Parts were significantly better recognized than Whole stimuli for 13- to 14-year-olds ($p < .05$), 11- to 12-year-olds, and 9- to 10-year-olds (both $ps < .01$). Considering Whole stimuli, adults did not differ from 15- to 16-year-olds; however, both groups were significantly better than all younger age groups ($ps < .05$). The 13- to 14-year-olds did not differ from the 11- to 12-year-olds but both groups were significantly better than the 9- to 10-year-olds ($ps < .01$). Considering Part stimuli, Adults were significantly better only than the 9- to 10-year-olds ($p < .05$); there were no other reliable differences.

For the Inverted stimuli, again both main effects and the interaction between Age and Target Type were significant (all $ps < .001$). Considering the difference between the two Target Types at each age range by Newman–Keuls pairwise comparisons, Parts were recognized significantly better than Whole stimuli at all ages ($ps < .05$) except for the 13- to 14-year-olds. Considering Whole stimuli, it is clear that the participants found them particularly difficult, though all groups performed better than chance. Adults, 15- to 16-year-olds, and 13- to 14-year-olds did not differ; however, all three of these groups scored significantly better than the other two groups ($ps < .01$). Considering Part stimuli, the only reliable differences were that Adults were better than the 13- to 14-year-olds and 9- to 10-year-olds ($ps < .05$).

The effects of disrupting spatial relationships between parts were considered from the interaction between Age and Orientation for Whole stimuli; it gave $F(4, 115) = 2.58$, $p = .041$. Newman–Keuls pairwise comparisons showed that there were reliable differences between Upright and Inverted presentations for Adults, 15- to 16-year-olds and 11- to 12-year-olds ($ps < .01$) but not for 13- to 14-year-olds or 9- to 10-year-olds. The comparable interaction for Part stimuli gave $F(4, 115) < 1$ in the context of a reliable advantage for Upright stimuli [$F(1, 115) = 16.81$, $p < .001$].

Discussion

The most conspicuous finding in Study 3 is the tardy development of animal Whole recognition. Study 3 found that children have reached adult levels of performance for Whole stimuli only at 15 to 16 years of age. We note a similar tardy pattern of performance for face recognition (Carey, 1992; Chung & Thomson, 1995). In those studies, the late development is ascribed to children's difficulty with configural processing. The second most important finding concerns the effects of inversion. As predicted, inversion had more dramatic effects on the recognition of Whole stimuli. We now compare and contrast the present tasks to those used in the examination of face recognition.

Inversion impairs only recognition of whole faces and not that of face parts (Leder & Bruce, 2000; Searcy & Bartlett, 1996; Tanaka & Farah, 1991) and this is also true for children over 5 years old (Tanaka et al., 1998). In our data, the 10-year-old children demonstrated a reliable advantage for upright part stimuli but the advantage did not alter with age. We would suggest that animal parts are also recognized equally well after inversion but, in parallel, whole representations favoring upright presentations are always involved when identifying basic-level animals. Indeed, if recognition of inverted animals were easy from parts alone, Study 1 should predict that 5-year-olds would have considerable success in naming inverted animals and our pilot study indicated they do not. The automatic access to the whole representations responsible for the part inversion advantage would be consistent with the results of recent object naming studies (Stankiewicz, Hummel, & Cooper, 1998; Stankiewicz & Hummel, in press). Their work proposed "holistic surface maps" to explain why only priming from unattended objects is sensitive to orientation changes such as inversion. However, a different mechanism would be required to explain the more dramatic effects of inversion on the processing of Whole animal stimuli.

Carey and Diamond (1994) have proposed that there are two mechanisms responsible for wholistic face processing. The first of these is biologically endowed or acquired early (Deruelle & de Schonen, 1991; Goren, Sarty, & Wu, 1975; Johnson, Dziurawiec, Ellis, & Morton, 1991). It is the mechanism that is sensitive to contour alignment and which causes the child difficulty in identifying the two half-faces in inverted face composites (Carey & Diamond, 1994; Young, Hellawell, & Hay, 1987). It is similar to the mechanisms described above (Stankiewicz et al, 1998; Tanaka & Sengco, 1997) responsible for the superior performance in our Part task with upright rather than inverted stimuli. The second mechanism of Carey and Diamond (1994) is acquired and matures in adolescence and is based on the configural relationships between features. Its expertise could rely on the establishment of a prototype and the understanding of deviations from that norm-based code (Bartlett & Searcy, 1993; Rhodes, Brake, & Atkinson, 1993; Tanaka & Sengco, 1997). The second mechanism would explain the data from our Whole stimuli. The impairments produced by inversion for animal Whole recognition appear at much the same age as the corresponding changes noted both behaviorally (Carey, 1992; Schwarzer, 2000) and neurophysiologically (Jeffreys, 1996) in face processing.

There is another respect in which the present work on animal recognition is somewhat similar to that on face recognition. Adult levels of performance for feature recognition would appear to be reached by the 11- to 12-year-olds with the exception of a dip in performance for inverted parts from the 13- to 14-year-olds. Carey et al. (1980) reported a decline or, at least a plateau, in performance for face recognition around 12 years of age. At this age, they comment on a transition in the way face recognition is performed. There may also be a similar transition in the way inverted animal stimuli are dealt with by the 13- to 14-year-old group. Like the younger groups, the 13- to 14-year-olds found the upright part items easier to differentiate than the upright whole items. However, the 13- to 14-year-olds were the only age group not to find inverted parts easier than inverted whole stimuli; nor did they find upright whole easier than inverted whole stimuli. These children also showed a marked increase in performance on inverted whole stimuli compared to the 11- to 12-year-olds. Indeed, the absolute performance on inverted whole items is not reliably greater for adults than it is for 13- to 14-year-olds.

As the children know the identity of the animal, it is reasonable to believe that they attempt recognition of the correct inverted whole stimuli by mental rotation; a skill of extremely limited use for object recognition (Lawson, 1999). Mental rotation for complex shapes is an ability that increases with age (Courbois, 2000) and for our stimuli a leap in performance is observed for the 13- to 14-year-olds. Carey et al. (1980) attributed the surprising lack of improvement in face recognition in 11- to 12-year-olds to the action of developing configural skills on the extant featural skills. There are clear differences between the present data and those of Carey et al. (1980); not least that the dip in performance was found here for inverted rather than upright stimuli. Nevertheless, we would likewise speculate that a developing skill might be used inappropriately. The use of mental rotation skills for inverted part stimuli could interfere with their identification and cause the nonmonotonic performance dip.

GENERAL DISCUSSION

The development of the child's recognition of animals from the age of 5 until adulthood was studied. These results emphasize the role of parts in animal recognition and the late development of an equivalent ability to recognize the whole shape of animals. Our research showed that superiority for parts in the recognition of animals extends well into the early school years. Even 9- to 10-year-olds have limited ability to recognise an animal by its shape and it is only 15- to 16-year-olds who demonstrated Whole recognition equal to their Part recognition.

Thus, it is around 16 years of age that we find an adult level of performance for Whole stimuli.

A central question for further research would concern the youngest age at which long-term representations used for recognition describe configural relations between parts. It would appear that even infants are capable of making category judgments of geometric figures by shape (Bomba & Siqueland, 1983; Milewski, 1979). The 4-year-old's ability to deal with configural stimuli is considerably greater (Abecassis et al., 2001; Sophian, 2000). Indeed, they prefer to generalize novel words to configurally similar objects rather than to objects within the categorical shape distinctions that are important for adults (Abecassis et al., 2001). Four-year-old children were even able to judge relational correspondences between animal-like shapes (Sophian, 2000). The results of Sophian (2000) would suggest that the abilities the child would require for the animal Whole task are dormant in the early school child. So, if children as young as five have some notion of the relation between animal parts, the question arises whether their performance in our tasks is a result of a strategic use of part representations or a result of the late acquisition of sufficiently detailed whole representations.

Strategic aspects of children's abilities are clearly seen in their drawing (Sutton & Rose, 1998). The development of realistic drawings was related to the child's scanning of the object being drawn; this predicted the type of drawing made (Sutton & Rose, 1998). In the present study, we did not examine effects of strategy. However, it may well be that only when children are asked to compare an animal they have drawn from memory to its picture is there a need to lay down representations containing spatial relationships between parts of animals. Even this may be ineffective, as 6-year-old children are, for example, much more satisfied with their own drawings of objects than with more realistic alternatives containing a greater number of parts (Moore, 1986). We would thus not favor a strategic explanation for the present results but rather point to the effect of goal directed experience in laying down whole representations.

We make the parsimonious proposal that the child lays down the minimal representation sufficient for naming (Davidoff & Warrington, 1999). The child's experience does not generally require the learning of an animal's shape with any precision. Experience with animals does not require children to distinguish between, say, fat or thin animals as a farmer may have to. It would, therefore, be interesting to see if our results were maintained for family pets or other individual animals with which the child may be extremely familiar. Indeed, Diamond and Carey (1977) showed that the addition of paraphernalia (e.g., hats) that was successful in making 5-year-old children misrecognize unfamiliar faces (see also Freire & Lee, 2001) did not readily confuse them for familiar faces.

Turning to the implications of our study for naming, the present results suggest that the visual knowledge used in naming by young children is strictly limited and largely restricted to parts. If children learn to differentiate animal categories by overall shape (Clark, 1973; Landau et al., 1998), then it must be from some gross aspect of contour similarity. However, while maintaining that the young child's representations used for naming are largely based on parts, this does not necessarily imply that naming is a dumb attentional mechanism relying on visual rather than functional knowledge of an object (Landau et al., 1998; Smith, Jones, & Landau, 1996). Perceptual and functional knowledge could interact to emphasize parts in animal representations. Children will certainly have a deeper knowledge of animals than simply their appearance and they might wish to call upon that knowledge when giving an animal a name (Neisser, 1987). The whole object could play little part in our other knowledge concerning animals, whereas animal parts could play critical roles. In monkeys, for example, the long tails have a function because they use them as a purchase when swinging through trees. The two types of knowledge may interact, thus favoring laying down representations of animals by their parts.

In summary, our data show that both part and whole representations are important aspects of object recognition for animals (see also Moscovitch, Winocur, & Behrmann, 1997). However, it is only for 10-year-olds that we have any substantial evidence that children can distinguish between our Whole animal changes. The late development for representations that deal with animal shape may have several causes. The infant's on-line success in categorizing animals by heads and faces could promote attention to other parts rather than the whole shape in the first few years of life. The child's acquisition of knowledge concerning animals could then accentuate this attention to parts. The acquisition of language could further contribute toward a concentration on parts because only animals with similar parts to those already used for recognition would be given the same name. The predominance of part representations would be accentuated because alternative norm-based representations demand more resources and are only relevant to questions of subordinate classification ("Whose face?" and "Whose cat?"). Thus, the tardiness of detailed whole recognition may lie in the rather parsimonious representations that would appear to perform adequately for object naming.

APPENDIX

List of Stimuli for Animal Parts and Wholes

Part	*Whole*
Caterpillar head	Bear
Chicken feet	Chicken
Chicken head	Cow
Cockerel head	Donkey
Cow body	Duck
Cow head	Eagle
Donkey ears	Fly
Duck tail	Frog
Fish head	Giraffe
Fox tail	Goat
Goose head	Horse
Goat legs	Kangaroo
Horse tail	Leopard

APPENDIX—*Continued*

Part	Whole
Lion tail	Monkey
Mouse tail	Ostrich
Rhino body	Penguin
Seal head	Seal
Sheep legs	Snail
Swan head	Squirrel
Tiger tail	Swan

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