Developmental Science 8:3 (2005), pp 240–254

PAPER

Can chimpanzee infants (*Pan troglodytes*) form categorical representations in the same manner as human infants (*Homo sapiens*)?

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Abstract

We directly compared chimpanzee infants and human infants for categorical representations of three global-like categories (mammals, furniture and vehicles), using the familiarization–novelty preference technique. Neither species received any training during the experiments. We used the time that participants spent looking at the stimulus object while touching it as a measure. During the familiarization phase, participants were presented with four familiarization objects from one of three categories (e.g. mammals). Then, they were tested with a pair of novel objects, one was a familiar-category object and another was a novel-category object (e.g. vehicle) in the test phase. The chimpanzee infants did not show significant habituation, whereas human infants did. However, most important, both species showed significant novelty-preference in the test phase. This indicates that not only human infants, but also chimpanzee infants formed categorical representations of a global-like level. Implications for the shared origins and species-specificity of categorization abilities, and the cognitive operations underlying categorization, are discussed.

Introduction

Categorization is one of the most significant cognitive skills required for adequately adapting to a dramatically changing environment. An important issue in the study of human cognitive development concerns the origin of categorization abilities and how they develop throughout the individual's life. In light of this, many recent studies have investigated whether human infants possess the basic ability to categorize objects (e.g. Behl-Chadha, 1996; Mareschal & Quinn, 2001; Quinn, 1998; Rakison & Butterworth, 1998; Younger & Fearing, 1999, 2000).

For instance, Quinn, Slater, Brown and Hayes (2001) examined categorization of geometrical figures (triangles, circles, squares and crosses) in newborn infants and 3- to 4-month-old infants using the familiarization–novelty preference task. In this study, newborns and 3- to 4-month-old infants were first familiarized with six exemplars from one of the four categories (i.e. triangles). Then, they were tested with a pair of exemplars containing a novel exemplar from the familiar category (i.e. a new triangle) and a novel exemplar from the novel category (i.e. a circle). Results showed that older infants significantly preferred the novel category exemplar to the familiar category exemplar, whereas, in general, newborn infants did not. However, newborns did show a significant novelty-preference when they were familiarized with crosses, and then tested with circles, triangles or squares. Quinn *et al*. (2001) proposed that newborn infants had formed a broader 'categorical representation' for open-figure stimuli (crosses) that exclude closed-figure stimuli (triangles, circles, squares). Older infants, according to Quinn *et al*. (2001), had formed individuated categorical representations for triangles, circles, squares and crosses, in the same manner as adults. These results indicate that even newborn human infants possess the basic capacity for categorization, and that categorization changes during development.

Many other studies have also shown interesting results for categorization by human infants (e.g. Oakes, Madole & Cohen, 1991; Quinn, Eimas & Rosenkrantz, 1993). This raises the questions of whether there are certain

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innate abilities that underlie categorization seen in human children and adults. If so, how did humans acquire such abilities during evolution, and how does human categorization differ from that of non-human animals?

Recently, many authors have argued that categorization ability is not restricted to humans. For example, many species of non-human primates have been shown to respond categorically to objects in various tasks (e.g. same/different tasks, discrimination tasks): squirrel monkeys (*Saimiri sciureus*) (e.g. Phillips, 1996); baboons (*Papio anubis*) (e.g. Bovet & Vauclair, 1998); rhesus monkeys (*Macaca mulatta*) (e.g. Neiworth & Wright, 1994); gorillas (*Gorilla gorilla gorilla*) (e.g. Vonk & MacDonald, 2002); chimpanzees (*Pan troglodytes*) (e.g. Tanaka, 2001). These findings provide much information about categorization by non-human primates, and provide some clues about the evolutionary origins of human categorization.

However, some investigators have noted that most of these studies have some experimental limitations (e.g. Brown & Boysen, 2000). First, during the experiment, participants are usually explicitly trained to categorically respond to objects, with reinforcements for their correct responses, until they reach a pre-defined criterion. This limitation inevitably restricts the possible conclusion that non-human primates spontaneously categorize objects in the same manner as humans. Second, data are lacking on the early development of categorization in non-human primates. In other words, there is a lack of information concerning categorization in non-human primate infants in terms of both ontogeny and phylogeny.

In a study relevant to these issues, Murai, Tomonaga, Kamegai, Terazawa and Yamaguchi (2004) investigated whether infant Japanese macaques (*Macaca fuscata*) could form categorical representations of such objects as mammals, furniture and vehicles without any training, as reported in human infants. They used the paired familiarization–novelty preference method used in the studies of human infants (e.g. Behl-Chadha, 1996; Eimas, Quinn & Cowan, 1994; Quinn *et al.*, 1993), in which subjects' looking time to objects was used as a dependent measure. The experiments consisted of a familiarization and a test phase. During the familiarization phase, the participants were presented twice with two pairs of different objects from one category (for example, two pairs of vehicles). After the fourth familiarization trial, they were presented twice with a test pair of a novel same-category object and a novel different-category object (for example, a new vehicle and a mammal). If participants could categorize objects, their looking time would gradually decrease in the familiarization phase, as they habituated to within-category objects. Moreover, in the test phase, their looking time to novel-category objects would be longer than that to novel familiar-category objects. The results showed that, although the decrease in looking time across the familiarization trials was not significant, participants' looking time to the novel-category objects was significantly longer than that to novel familiar-category objects in the test phase. These novelty-preferences suggested that infant macaques discriminated among objects in terms of category, that is, they formed categorical representations without any training, like human infants.

The results obtained with infant macaques motivated us to examine whether there is a fundamental categorization ability shared between non-human primate infants and human infants. In the experiments reported here, we examined whether infants of another non-human primate species, chimpanzees, would form categorical representations of objects based on their features. If chimpanzee infants showed similar categorization abilities as seen in human infants, it would reinforce the view that the origins of human categorization may be traced to the common ancestor with non-human primates. Moreover, if there were differences between the two species, there would be a requirement for further examination of species-specific categorization abilities, and their cognitive underpinnings.

A number of studies have tested categorization abilities in adult chimpanzees, and have found that chimpanzees and humans possess similar categorization processes (e.g. Brown & Boysen, 2000). However, few studies have directly compared early spontaneous categorization in the two species using identical methods. Among these few studies, Spinozzi and her colleagues (Spinozzi, Natale, Langer & Schlesinger, 1998; Spinozzi, 1993) compared the development of spontaneous sorting behavior by chimpanzee infants between the ages of 15 and 54 months and by human infants between the ages of 6 and 24 months, using sets of simple objects that were logically related in form (cups, rings, blocks and crosses) and color (blue, green, yellow and red) as stimuli. In this study, the participants were presented with a set of six objects in each trial. These objects were divided into two classes that differed from each other in one of their two properties, either color (three red cups and three yellow cups) or form (three red cups and three red rings), or differed in both color and form (three blue crosses and three green blocks). Spinozzi and her colleagues (1998; Spinozzi, 1993) analyzed participants' constructive interactions with these sets of objects. They concluded that chimpanzees spontaneously sorted objects based on both properties, and that development of sorting behavior in chimpanzee infants seemed to be similar to that of human infants.

The key feature of the current study was that chimpanzee infants and human infants were tested with an identical procedure (the familiarization–novelty preference technique), and neither species was trained in any way with reinforcement for their responses during the experiments.[1] Previously, some studies of chimpanzee categorization have used a same/different task or a sorting task (e.g. Brown & Boysen, 2000; Spinozzi, 1993; Spinozzi *et al.*, 1998). However, this is the first study using the familiarization–novelty preference procedure to investigate chimpanzee categorization. We used the time that participants spent looking at objects while they touched the objects as a measure of interest. That is, we assessed their careful examination of stimulus objects. Thus, participants were allowed to actually act on objects rather than to simply look at them. Usually, just participants' looking time to objects is used as a measure in preferential-looking or habituation methods. However, according to Oakes, Madole and Cohen (1991), simple looking time may involve passive reaction to objects, whereas examination time reflects active processing of objects (see also Mareschal, Powell & Volein, 2003). Therefore, we gave the chimpanzee infants and human infants the opportunity to actually manipulate objects during the experiments. We used 3-D scale models as stimuli; these were expected to be explored not only visually but also manually, and thus to enhance responses by participants (see Mandler & McDonough, 1993; Pauen, 2002).

In the present study, we used three global-like categories (namely, mammals, furniture and vehicles) defined by human adult experimenters. Originally, it was thought that global-level categorization is more difficult than basic-level categorization, because global-level categories (i.e. animals) have low within-category similarities, whereas basic-level categories (i.e. dogs) have high within-category similarities (e.g. Rosch, Mervis, Gray, Johnson & Boyes-Braem, 1976). Thus, to form global-level categories, it would be necessary to regard objects of very different appearance as 'the same kind'. In other words, global-level categorization involves the processing of abstract properties among objects, whereas basic-level categorization is possible via processing of accessible perceptual similarities among objects. However, recently, some studies using the familiarization–novelty technique have provided evidence that even young human infants form some global-level categories, such as mammals, vehicles and furniture (e.g. Behl-Chadha, 1996; Mandler & McDonough, 1996). In these studies, it was suggested that global-level categories would appear earlier than basic-level categories, even though it is still unclear what kinds of object properties are available to form such categories. Some researchers believe that global-level categorization would be based on perceptual properties of objects (e.g. Quinn, 1998; Rakison & Butterworth, 1998), whereas others argue that it would be based on conceptual properties (e.g. Mandler & McDonough, 1993).

Brown and Boysen (2000) suggested that adult chimpanzees spontaneously formed some basic-level categories (cats, tigers, chimpanzees, gorillas and fish) in a same–different task without differential reinforcement. In contrast, evidence that chimpanzee infants, or even adults, categorize objects at the global level is lacking. Here, we were interested in whether chimpanzee infants can form categorical representations of global-like level as seen in human infants, and what the similarities and differences between chimpanzees and humans are in terms of comparative and developmental psychology. Therefore, we first investigated how chimpanzee infants respond to objects forming global-like categories in Experiment 1, and then we compared performances of the two species in Experiment 2.

Experiment 1

In Experiment 1, we examined whether chimpanzee infants respond categorically to objects from three global-like categories (mammals, furniture and vehicles) without any training. We used the familiarization–novelty preference technique that is widely used to examine categorization in human infants (e.g. Arterberry & Bornstein, 2001; Behl-Chadha, 1996; Eimas, Quinn & Cowan, 1994).

Method

Participants

Three infant chimpanzees (*Pan troglodytes*), named Ayumu (male), Cleo (female) and Pal (female), participated in this experiment. Ayumu was tested from 416 to 693 days of age (14–23 months), Cleo was tested from 360 to 618 days of age (12–20 months) and Pal was tested from 309 to 562 days of age (10–18 months). They were born at the Primate Research Institute of Kyoto University and reared by their mothers from birth. The

[1] We described how our participants did not go through supervised training. However, it is possible that in the familiarization phase they were learning something relevant to the category discrimination, and that as a result they would subsequently be trained on discrimination of objects. That is, the tasks involving familiarization may be in fact unsupervised training tasks. We want to emphasize, however, that our participants, even chimpanzee infants, were not reinforced to perform correctly by some rewards in a similar way to the previous study on categorization in animals.

infants are members of a community of 14 chimpanzees and live in an enriched outdoor compound with another 11 chimpanzees including their mothers (Ochiai & Matsuzawa, 1998). These infants had participated in a research project on chimpanzee development, and had therefore experienced a variety of tests related to the development of cognitive abilities (e.g. Hirata & Celli, 2003; Matsuzawa, 2003; Myowa-Yamakoshi, Tomonaga, Tanaka & Matsuzawa, 2003; Sousa, Okamoto & Matsuzawa, 2003; Tanaka, Tomonaga & Matsuzawa, 2003; Tomonaga, Tanaka & Matsuzawa, 2003). The care and use of the chimpanzees adhered to the 2002 version of the manual 'Care and use of laboratory primates' of the Primate Research Institute of Kyoto University, and the experimental designs were accepted by the Animal Welfare and Animal Care Committee of the Institute.

Stimuli

The stimuli were 60 three-dimensional lifelike scale models of exemplars from mammal, furniture and vehicle categories. Each category had 20 objects. The objects varied in size and color. The size of objects ranged from 4 cm to 6 cm in length and 3 cm to 4 cm in height. The mammals were made from rubber or plastic, and had no moving parts. The furniture exemplars were made from wood or plastic. The vehicles were made from plastic or metal. Any moving parts of furniture and vehicles (e.g. a drawer, the wheels and the doors) were glued immobile.

Procedure

Categorization test. The participant entered the experimental acrylic booth (2 m × 2 m × 2.4 m) with his/her mother and was tested there individually. One human experimenter entered the booth along with the mother–infant pair. This experimenter recorded the participant's behavior toward objects using a small digital video camera (SONY CCD MC-100), while the second experimenter recorded the experimental situation using a digital video camera (SONY DCR TRV-9) from outside the booth. During the experiment, the participant was allowed to move freely around the booth. The familiarization–novelty preference task consisted of a familiarization and a test phase. The time that the participants spent looking at the stimulus objects while touching them was used as a dependent measure, described as looking while touching time (hereinafter LWT). During the familiarization phase, the participant was presented with four familiarization objects from one category, one at a time. Each object was held in the experimenter's hand so that the participant could not take it. Because the participants tended to put the objects in their mouth following only a brief examination, we tried to prevent this by holding the object in the experimenter's hand. The familiarization objects were selected randomly from the set of 20 objects for each session. Each trial lasted 15 s, beginning with the participant's first LWT. Intertrial interval was about 10 s. However, it was occasionally extended. For example, if the participant was away from the experimenter at the planned start time for the next trial, the experimenter delayed the presentation of the object until the participant came close to him. After the fourth familiarization trial, the participant was presented with a test pair of objects: one was a new object from the now-familiar category, and the other was from a novel category; that is, from one of the remaining two categories. The test objects were placed on the floor within reach of the participant, so that the latter could freely manipulate them. The distance between the two objects was about 15 cm. The test objects were also randomly selected from each category for each session. The left-right positioning of the two objects was counterbalanced across sessions. Test trials lasted 15 s, beginning with participant's first LWT. Thus, one session consisted of four familiarization trials and one test trial.

There were two kinds of test pairs for each familiarization condition. For instance, when the participants were familiarized with mammals, they were tested with a mammal (novel familiar-category) and a furniture exemplar (novel-category), or a mammal (novel familiar-category) and a vehicle (novel-category). Either kind of test pair was used in one session, the order being counterbalanced across sessions in each condition. All participants received 6 sessions for each test pair; that is, they received 12 sessions overall in each familiarization condition.

If participants categorized objects, their LWTs should gradually decrease in the familiarization phase, that is, they should habituate to the objects. Also, their LWTs to novel-category objects should be longer than that to novel familiar-category objects in the test phase. That is, they should prefer novel-category objects to novel familiar-category objects.

Scoring. All trials were videotaped for later scoring. To assess the amount of LWT, one of the experimenters calculated the number of frames (one frame = 1/30 sec) in which the participants looked at objects while touching them, using Adobe Premire software on a computer (SONY, VAIO PCV-RX63). Behaviors such as simply looking, and simply touching (or mouthing) without looking were not considered. A second coder, who was blind to the aim and the hypothesis of this study, coded LWTs for 25% of all sessions for each participant to provide an indication of inter-observer reliability. The

Table 1 *Mean (and SE) LWTs (in sec.) in the preference test by chimpanzee infants*

		Category contrast					
		mammal vs. furniture		vehicle vs. furniture		mammal vs. vehicle	
		mammal	furniture	vehicle	furniture	mammal	vehicle
Ayumu	*M*	1.91	2.52	1.97	3.22	1.53	2.26
	SE	0.36	0.59	0.56	0.52	0.22	0.34
Cleo	*M*	1.65	2.04	3.00	1.74	2.41	1.35
	SE	0.52	1.00	0.57	0.66	0.30	0.54
Pal	*M*	2.89	0.71	1.46	1.44	3.80	0.31
	SE	0.65	0.30	0.59	0.68	0.46	0.18

Pearson correlation between the two coders' LWTs was calculated, and the mean correlation was $r = .92$.

Preference test. Preference tests were conducted to examine whether the participants had any intrinsic preference for a particular category. The procedure was almost the same as in the categorization test described above, except that the participants were presented with neutral objects during familiarization. In the familiarization phase, the participants were presented with four neutral objects (wooden bricks varying in shape and color). In the test phase, they were presented with a pair of objects from two categories. Test objects were chosen randomly for each session from the set of stimuli used in Experiment 1. The pair was presented twice and the left-right positioning of objects was counterbalanced across trials. There were three contrasts generated from combinations of three categories: mammal vs. furniture, vehicle vs. furniture, and mammal vs. vehicle. One type of contrast was tested in a session, with the order counterbalanced across sessions. All participants received 8 sessions for each contrast; that is, they received 24 sessions overall.

Results

Preference test

Familiarization phase. Participants' LWTs were averaged across the first two trials (the first block) and across the last two trials (the second block) for each category contrast. A one-way ANOVA was then performed for each participant with trial block (with two levels: the first block and the second block) as a within-subjects factor. For Ayumu, the main effect of block was significant, $F(1, 23) = 7.20$, $p < .05$: LWT decreased from the first block ($M = 3.43$ s, $SE = 0.58$) to the second block ($M = 1.81$ s, $SE = 0.43$). However, neither Cleo nor Pal showed such a significant decrease (for Cleo, first block: $M = 2.75$ s, $SE = 0.46$, second block: $M = 2.35$ s, $SE = 0.39$, $F(1, 23) = 0.93$, $p > .10$; for Pal, first block: $M = 2.40$ s, $SE = 0.49$, second block: $M = 2.43$ s, $SE = 0.43$, $F(1, 23) = 0.00$, $p > .10$).

Test phase. Participants' LWTs to each object in each test pair were averaged across the two test trials for each category contrast. The mean LWTs in this phase are shown in Table 1. A one-way ANOVA was performed on the data for each category contrast and each participant with category (with two levels) as a within-subjects factor. Ayumu and Cleo showed no main effect of category on any contrast (for Ayumu, mammal vs. furniture: $F(1, 7) = 2.05$, $p > .10$, vehicle vs. furniture: $F(1, 7) = 1.41$, $p > .10$, mammal vs. vehicle: $F(1, 7) = 2.48$, $p > .10$; for Cleo, mammal vs. furniture: $F(1, 7) = 0.09$, $p > .10$, vehicle vs. furniture: $F(1, 7) = 1.07$, $p > .10$, mammal vs. vehicle: $F(1, 7) = 1.80$, $p > .10$), suggesting that neither participant had any intrinsic preference for a particular category. For Pal, the main effect of category was not statistically significant for the contrast of vehicle vs. furniture, $F(1, 7) = 0.00$, $p > .10$. However, for the contrast of mammal vs. furniture and that of mammal vs. vehicle, the main effect of category was significant (mammal vs. furniture: $F(1, 17) = 6.45$, $p < .05$, mammal vs. vehicle: $F(1, 17) = 32.70$, $p < .01$), suggesting that Pal preferred mammals to the two other categories.

Category test

Familiarization phase. Participants' LWTs were averaged across the first two trials (the first block) and across the last two trials (the second block) in each familiarization condition. Mean LWTs in the familiarization phase are shown in Table 2. A two-way ANOVA was performed for each participant with familiar category (with three levels: mammals, furniture and vehicles) and trial block (with two levels: first and second block) as within-subjects factors. The main effect of trial block was not significant for any participant (for Ayumu, $F(1, 11) = 0.01$, $p > .10$; for Cleo, $F(1, 11) = 4.59$, $p < .10$; for Pal,

Table 2 *Mean (and SE) LWTs (in sec.) in the familiarization blocks by chimpanzee infants*

		Familiar category					
		mammal		furniture		vehicle	
		block 1	block 2	block 1	block 2	block 1	block 2
Ayumu	*M*	1.04	1.83	4.01	3.28	3.47	3.32
	SE	0.31	0.21	0.54	0.36	0.57	0.49
Cleo	*M*	0.80	0.58	2.49	1.75	2.46	0.79
	SE	0.23	0.22	0.81	0.56	0.85	0.22
Pal	*M*	2.14	2.55	3.67	3.35	1.29	1.73
	SE	0.48	0.87	0.87	0.72	0.52	0.59

$F(1, 11) = 0.12$, $p > .10$), suggesting that LWT did not decrease across trials. Ayumu and Pal showed a significant main effect of familiar category (for Ayumu, $F(2, 22) = 12.02$, $p < .01$; for Pal, $F(2, 22) = 4.57$, $p < .05$). LSD post-hoc comparisons confirmed that, for Ayumu, LWT to furniture and vehicles was longer than that to mammals, while for Pal, LWT to furniture was longer than to vehicles.

Discrimination between familiarization objects. We conducted another analysis to evaluate whether participants could discriminate between the familiarization objects. We reasoned that, if they could not discriminate between the familiarization objects, their LWTs would continue to decline over the familiarization trials even when they were presented with new familiarization objects. In contrast, if they could discriminate between the familiarization objects, their LWTs would recover when they were presented with new ones. To resolve this issue, we analyzed in detail participants' LWTs during familiarization trials for 20% of all sessions. We divided each 15 s familiarization trial into the three sections of the first 5 s, the middle 5 s and the last 5 s. Then, we analyzed how much LWT decreased from the first section to the last section of the first trial. Likewise, we compared the LWT in the first section with that in the last section of each trial. Next, we analyzed how much LWT increased from the last section of the first trial to the first section of the second trial. Likewise, we compared the LWT in the last section of a trial with that in the first section of the following trial. In this way, we evaluated whether participants discriminated between the two successive objects in the familiarization phase. The *t*-tests revealed that there were significant decrements of LWT between the first section and the last section within all trials (for the first trial, the first section: $M = 2.29$ s, $SE = 0.30$, the last section: $M = 0.76$ s, $SE = 0.21$, $t(20) = 5.58$, $p < .01$; for the second trial, the first section: $M = 2.28$ s, $SE = 0.36$, the last section: $M = 0.80$ s, $SE = 0.26$, $t(20) = 4.78$, $p < .01$; for the third trial, the first section: $M = 2.09$ s, $SE = 0.31$, the last section: $M = 0.90$ s, $SE = 0.23$, $t(20) = 3.47$, $p < .05$; for the fourth trial, the first section: $M = 2.07$ s, $SE = 0.26$, the last section: $M = 0.64$ s, $SE = 0.21$, $t(20) = 4.48$, $p < .01$). Furthermore, there were significant increases of LWT between the last section of the first trial and the first section of the second trial, $t(20) = 4.30$, $p < .01$, between the last section of the second trial and the first section of the third trial, $t(20) = 3.52$, $p < .05$, and between the last section of the third trial and the first section of the fourth trial, $t(20) = 3.66$, $p < .05$. These results suggest that participants habituated to the object in each trial, therefore they really processed individual objects, and so that they also could discriminate between the familiarization objects.

Test phase. Participants' LWTs to each object from each test pair were averaged in each familiarization condition. Figure 1 shows the mean LWTs in the test phase. There were two kinds of test pairs for each familiarization condition as mentioned above. We pooled participants' LWTs to test objects across two test pairs to assess whether there was significantly more LWT to novel-category objects in each familiarization condition. A two-way ANOVA was performed for each participant with familiar category (with three levels: mammals, furniture and vehicles) and test object (with two levels: novel familiar-category and novel-category) as within-subjects factors. The main effect of test object was significant for all participants (for Ayumu, $F(1, 11) = 47.11$, $p < .01$; for Cleo, $F(1, 11) = 16.03$, $p < .01$; for Pal, $F(1, 11) = 13.90$, $p < .01$): LWT to novel-category objects was longer than that to novel familiar-category objects. These results indicate that all participants significantly preferred novel-category objects to novel familiar-category objects as a whole.

Novelty-preference for each category contrast. We conducted additional analyses to examine whether participants' novelty-preference was bi-directional in all category

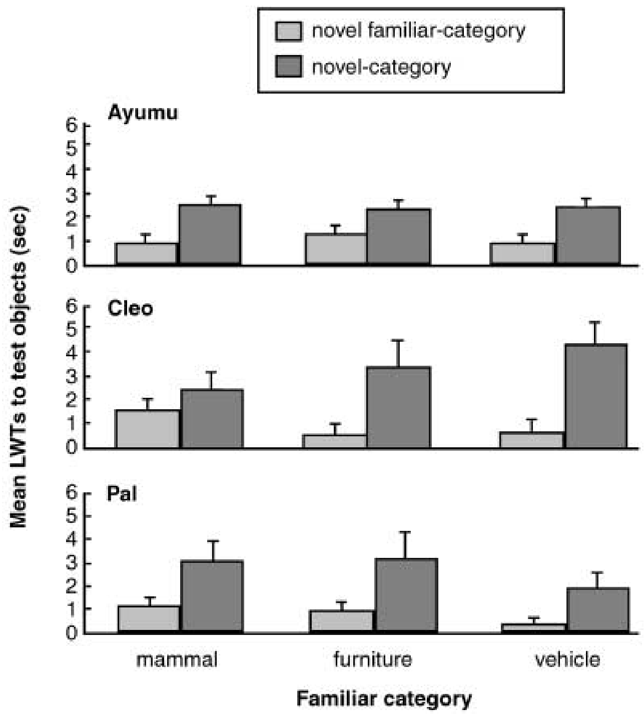

Figure 1 *The mean LWTs (with* SE *error bars) to each test object in each familiarization condition by chimpanzee infants.*

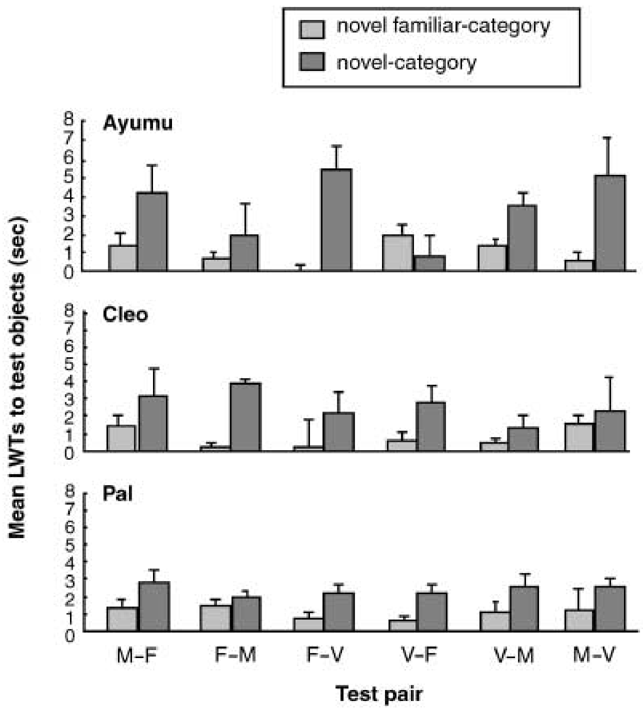

Figure 2 *The mean LWTs (with* SE *error bars) to each test object of each test pair by chimpanzee infants.*

contrasts, regardless of which category the participants were familiarized with. There were two kinds of test pairs for each category contrast. For instance, in the contrast of mammal vs. furniture, there were two test pairs of 'mammal–furniture' and 'furniture–mammal'. The 'mammal–furniture' pair meant that the participants were familiarized with mammals, then tested with mammal (novel familiar-category) and furniture (novel-category), while the 'furniture–mammal' pair meant that they were familiarized with furniture, then tested with furniture (novel familiar-category) and mammal (novel-category). We refer to 'mammal–furniture' pair as 'M–F', and 'furniture–mammal' pair as 'F–M'. Similarly, there were 'F–V (furniture–vehicle)' and 'V–F (vehicle–furniture)' pairs in the vehicle vs. furniture contrast, and 'V–M (vehicle–mammal)' and 'M–V (mammal–vehicle)' pairs in the mammal vs. vehicle contrast. We analyzed participants' LWTs to each object of each test pair. The results for each test pair are shown in Figure 2. A two-way ANOVA was performed for each participant with test pair (with six levels: M–F, F–M, F–V, V–F, V–M and M–V) and test object (with two levels: novel familiar-category and novel-category) as within-subjects factors. All participants showed a main effect of test object (for Ayumu, $F(1, 5) = 57.95$, $p < .01$; for Cleo, $F(1, 5) = 13.55$, $p < .05$; for Pal, $F(1, 5) = 35.96$, $p < .01$): their LWTs to novel-category objects were longer than that to novel familiar-category objects. Notably, the main effect of test pair was not significant (for Ayumu, $F(5, 25) = 0.39$, $p > .10$; for Cleo, $F(5, 25) = 1.56$, $p > .10$; for Pal, $F(5, 25) = 0.63$, $p > .10$), suggesting that participants' performance did not vary according to the test pairs. These results indicate that the significant novelty-preference was bi-directional in all category contrasts, regardless of the category the participants were familiarized with.

Discussion

No chimpanzee infant showed a significant decrease in LWT in the familiarization phase. That is, they did not habituate even after repeated presentation of the objects. How can this result be explained? One possible reason is that because four different objects were presented in each trial, participants' attention to objects would be maintained through the variation in objects during the familiarization phase. Indeed, Behl-Chadha (1996) reported that 3- to 4-month-old human infants also did not show habituation when they were presented with different familiarization objects (e.g. various chairs), and suggested that the diversity of familiarization objects would maintain their attention. In addition, inter-trial interval was too long at times. Because, the chimpanzee infants' behavior was not constrained during the experiment, it was hard to control exactly the inter-trial interval.

More importantly, however, all participants significantly preferred novel-category objects to novel familiar-category objects in the test phase. If they had not processed objects categorically at all in the familiarization phase, such consistent novelty-preference would not have been expected. Thus, the results of the test phase suggest that participants' performance in the familiarization phase does not reflect an inability to process the similarities among objects. Conceivably, the participants could not realize the similarities among familiarization objects until they were presented with an object in the contrasting category in the test phase. Therefore, these results suggest that infant chimpanzees may subsequently form categorical representations that exclude novel-category objects.

It should be noted that Pal showed an intrinsic preference for mammals in the preference test. Such a preference would accentuate her novelty-preference when the mammal category was presented to her as a novel-category object. However, she similarly showed a significant novelty-preference when the mammal category was familiar. Thus, Pal's response in the test phase was not simply dominated by her intrinsic preference.

The results of Experiment 1 indicate that chimpanzee infants spontaneously form categorical representation of objects at a global-like level. In Experiment 2, we tested human infants using the same method and compared the results directly with the results of chimpanzee infants.

Experiment 2

In Experiment 2, we tested human infants on categorical representation using the same procedure as in Experiment 1, to directly compare the responses between chimpanzee infants and human infants.

Method

Participants

Sixty-four human infants participated in this experiment. Forty-eight infants participated in the category test and the remaining 16 infants participated in the preference test, described below. In the category test, 48 participants were divided into two age groups: the younger group (24 infants, mean age: 14 months and 7 days; range: 10 months and 4 days to 17 months and 9 days), and the older group (24 infants, mean age: 21 months and 11 days; range: 18 months and 17 days to 24 months and 12 days). In each age group there were 12 girls and 12 boys. Infants were recruited through a pool of volunteer parents that responded to the invitation through the local newspaper. In the preference test, 16 infants were divided into two age groups: eight in the younger group (four girls, four boys, mean age: 14 months and 29 days, range: 12 months and 1 day to 17 months and 2 days), and eight in the older group (three girls, five boys, mean age: 21 months and 9 days, range: 18 months and 16 days to 22 months and 25 days). Another seven infants were tested but failed to complete the experiment due to fussing or crying.

Stimuli

The same 60 three-dimensional scale models as in Experiment 1 were used: 20 mammals, 20 furniture items and 20 vehicles.

Procedure

Category test. The procedure was essentially the same as in Experiment 1. Each infant was tested individually in the university laboratory, in the presence of the parent. The infant was seated on the parent's lap or on a baby chair at one side of a table. The first experimenter sat in front of the infant across the table, and presented stimulus objects to him/her. The second experimenter recorded the experimental situation on a digital video camera (SONY DCR-PC120). Parents were asked not to assist their infants in any way. During the familiarization trial, the infant was presented with four objects from one category, one at a time, which was held in the experimenter's hand. Familiarization objects were randomly chosen from 20 objects for each infant. Each trial lasted for 15 s, beginning with infant's first LWT. Inter-trial interval was about 10 s. After the fourth familiarization trial, the infant was presented with a test pair of objects: one was a new object from the familiar category, and the other was from a novel category. The test pair was placed on the table within reach so that the infant could freely manipulate the objects. The distance between the two objects was about 15 cm. Test objects were also randomly selected for each infant. The test pair was presented to participants twice. The left-right positioning of two objects was counterbalanced across trials. Each trial lasted for 15 s, beginning with infant's first LWT. Inter-trial interval was about 10 s. Thus, in Experiment 2, each session consisted of four familiarization trials and two test trials, and each infant participated in two sessions.

Each infant was randomly assigned to one of the three familiarization conditions: mammal, furniture and vehicle familiarization conditions. Therefore, eight infants were included in each condition for each age group. In

Table 3 *Mean (and SE) LWTs (in sec.) in the preference test by human infants*

		Category contrast					
		mammal vs. furniture		vehicle vs. furniture		mammal vs. vehicle	
		mammal	furniture	vehicle	furniture	mammal	vehicle
Younger	*M*	3.96	3.16	4.42	3.92	4.25	5.45
	SE	0.99	1.00	1.28	0.68	0.75	0.96
Older	*M*	5.18	6.01	6.82	3.35	3.60	5.95
	SE	0.97	0.67	0.92	0.79	0.98	1.20

each condition, the infant was first familiarized with four objects from one category (e.g. mammals), and tested with the first test pair (e.g. mammal vs. furniture). After the first session, the second familiarization phase started, in which four objects from the same category as in the first familiarization were presented and then the infant was tested with the second test pair (e.g. mammal vs. vehicle). The order of presentation of the two kinds of test pairs was counterbalanced across infants in each condition.

Scoring. Infants' LWTs to objects were calculated in the same way as in Experiment 1. The second coder, who was blind to the aim and the hypothesis of this study, coded the LWTs for 25% of all sessions for each age group to provide a measure of reliability. The Pearson correlation between each coder's LWTs was calculated, and the mean correlation was $r = .93$.

Preference test. The preference test procedure was essentially the same as in Experiment 1. Each infant received three sessions. In the first session, the infant was presented with four objects from a neutral category (wooden bricks) then tested with one of three test pairs (mammal vs. furniture, vehicle vs. furniture and mammal vs. vehicle). Each test pair was presented twice. The left-right positioning of the two objects was counterbalanced across trials. In the second and third sessions, infants were similarly familiarized with four wooden bricks, then tested with one of the remaining pairs. The order of presentation of the three kinds of test pairs was counterbalanced across infants in both age groups.

Results

Preference test

Familiarization phase. Infants' LWTs were averaged across the first two trials (the first block) and across the last two trials (the second block) for each category contrast. A two-way mixed design ANOVA was performed with age group (with two levels: younger and older) as a between-subjects factor and trial block (with two levels: first and second block) as a within-subjects factor. A main effect of trial block was found, $F(1, 46) = 20.68$, $p < .01$. A significant decrement in LWT from the first (younger, $M = 5.81$s, $SE = 0.56$; older, $M = 4.44$ s, $SE = 0.53$) to the second block (younger, $M = 4.97$ s, $SE = 0.56$; older, $M = 4.08$ s, $SE = 0.51$) was obtained.

Test phase. Infants' LWTs to each object of each test pair were averaged across the two test trials for each category contrast. The mean LWTs in this phase are shown in Table 3. A mixed-design ANOVA was performed for each category contrast with age group (with two levels: younger and older) as a between-subjects factor and category (with two levels) as a within-subjects factor. For all contrasts, there was no significant main effect of category (mammal vs. furniture, $F(1, 14) = 0.00$, $p > .10$; vehicle vs. furniture, $F(1, 14) = 4.51$, $p > .10$; mammal vs. vehicle, $F(1, 14) = 2.13$, $p > .10$), suggesting that there was no preference for any particular category.

Category test

Familiarization phase. Infants' LWTs were averaged across the first two trials (the first block) and across the last two trials (the second block) for each familiarization condition. Mean LWTs in the familiarization phase are shown in Table 4. A three-way mixed design ANOVA was performed, with age group (with two levels: younger and older) and familiar category (with three levels: mammals, furniture and vehicles) as between-subjects factors, and trial block (with two levels: first and second block) as a within-subjects factor. A main effect of trial block was found, $F(1, 90) = 12.87$, $p < .01$. A significant decrement in LWT from first to second blocks was obtained. Main effects of familiar category, $F(2, 90) = 4.28$, $p < .05$, and age group, $F(1, 90) = 6.41$, $p < .05$, were also significant. Moreover, the familiar category × age group interaction was significant, $F(2, 90) = 6.89$, $p < .01$. LSD post-hoc comparisons confirmed that

Table 4 *Mean (and SE) LWTs (in sec.) in the familiarization blocks by human infants*

		Familiar category					
		mammal		furniture		vehicle	
		block 1	block 2	block 1	block 2	block 1	block 2
Younger	*M*	5.36	3.97	8.72	8.11	7.08	6.94
	SE	0.81	0.67	0.67	0.81	0.68	0.87
Older	*M*	9.18	6.70	7.33	6.41	10.08	9.26
	SE	0.74	1.03	0.66	0.77	0.73	0.99

younger infants' LWTs to furniture were longer than to mammals, and their LWTs to vehicles were longer than to mammals. Among the older infants, LWTs to vehicles were longer than to mammals, and LWTs to mammals were longer than to furniture.

Discrimination between familiarization objects. We conducted another analysis to examine whether participants could discriminate between familiarization objects, as in Experiment 1. We analyzed in detail participants' LWTs during familiarization trials for 20% of all sessions, and performed *t*-tests on the data. The *t*-tests revealed that there were significant decrements of LWT between the first section and the last section within all trials (for the first trial, the first section: $M = 3.86$ s, $SE = 0.30$, the last section: $M = 2.28$ s, $SE = 0.44$, $t(19) = 3.34$, $p < .05$; for the second trial, the first section: $M = 4.19$ s, SE = 0.20, the last section: $M = 1.76$ s, $SE = 0.46$, $t(19) = 4.74$, $p < .01$; for the third trial, the first section: $M = 3.87$ s, $SE = 0.35$, the last section: $M = 1.51$ s, $SE = 0.39$, $t(19) = 5.23$, $p < .01$; for the fourth trial, the first section: $M = 3.42$ s, $SE = 0.42$, the last section: $M = 1.25$ s, $SE = 0.39$, $t(19) = 4.63$, $p < .01$). Moreover, there were significant increases of LWT between the last section of the first trial and the first section of the second trial, $t(19) = 4.50$, $p < .01$, between the last section of the second trial and the first section of the third trial, $t(19) = 4.27$, $p < .01$, and between the last section of the third trial and the first section of the fourth trial, $t(19) = 5.15$, $p < .01$. These results suggest that participants habituated to the object in each trial, and that they could discriminate between the familiarization objects.

Test phase. Infants' LWTs to test objects from each test pair were averaged for each familiarization condition. The results are shown in Figure 3. A mixed-design ANOVA was performed on these data, with age group (with two levels: younger and older) and familiar category (with three levels: mammals, furniture and vehicles) as between-subjects factors, and test object (with two levels: novel familiar-category and novel-category) as a within-subjects factor. The main effect of test objects was significant, $F(1, 90) = 24.94$, $p < .01$. Moreover, the familiar category × test object interaction was also significant, $F(2, 90) = 3.27$, $p < .05$. Further analysis revealed that a simple main effect of test object was significant when the familiar category was mammal, $F(1, 90) = 22.69$, $p < .01$, and furniture, $F(1, 90) = 7.47$, $p < .01$. These results indicate that infants significantly preferred novel-category objects to novel familiar-category objects when they were familiarized with mammals and furniture. However, no such difference was found when infants were familiarized with vehicles, $F(1, 90) = 1.33$, $p > .10$. The main effect of age group was also significant,

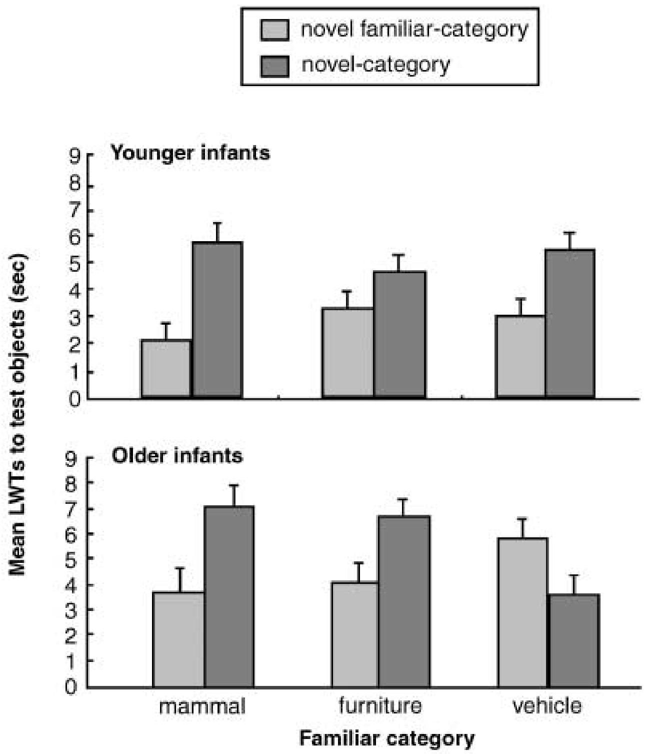

Figure 3 *The mean LWTs (with SE error bars) to each test object in each familiarization condition by human infants.*

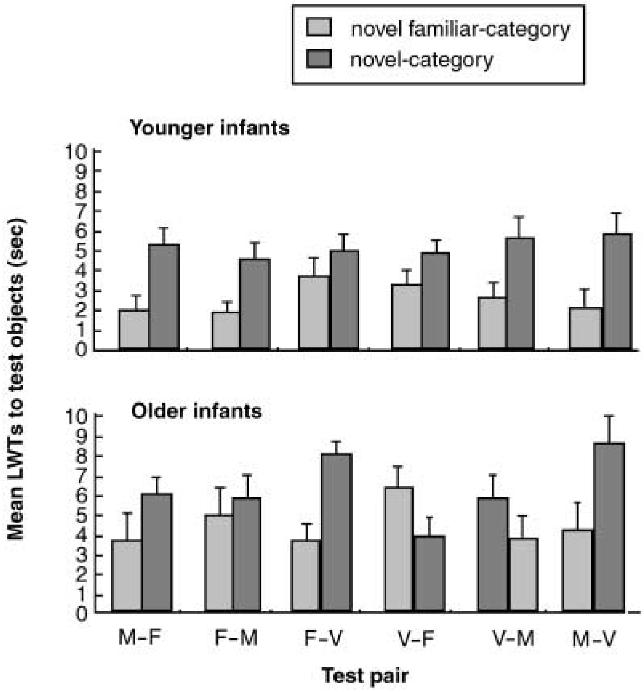

Figure 4 *The mean LWTs (with* SE *error bars) to each test object of each test pair by human infants.*

$F(1, 90) = 13.68$, $p < .01$, suggesting that LWTs of older infants were longer than those of younger infants.

Novelty-preference for each category contrast. In additional analysis, infants' LWTs to test objects were analyzed for each kind of test pair from three category contrasts, as in Experiment 1. The results for each test pair are shown in Figure 4. A three-way mixed design ANOVA was performed, with age group (with two levels: younger and older) and test pair (with six levels: M–F, F–M, F–V, V–F, V–M and M–V) as between-subjects factors and test object (with two levels: novel familiar-category and novel-category) as a within-subjects factor. This analysis revealed a significant main effect of test object, $F(1, 14) = 30.78$, $p < .01$. Moreover, there was a significant interaction between test object and test pair, $F(5, 70) = 2.48$, $p < .05$. Further analysis revealed that a simple main effect of test pair was significant in the novel-category objects, $F(5, 70) = 2.51$, $p < .05$. A simple main effect of test object was significant in the following four test pairs: 'M–F ($F(1, 14) = 11.75$, $p < .01$)', 'F–M ($F(1, 14) = 10.48$, $p < .01$)', 'F–V ($F(1, 14) = 10.36$, $p < .01$)', and 'M–V ($F(1, 14) = 7.71$, $p < .05$)', but not in 'V–F ($F(1, 14) = 0.26$, $p > .10$)' and 'V–M ($F(1, 14) = 0.18$, $p > .10$)'. These results revealed that infants significantly preferred novel-category objects to novel familiar-category objects when they were familiarized with mammals and furniture, but this preference did not reach significance when they were familiarized with vehicles.

Discussion

In contrast to chimpanzee infants, in the familiarization phase, human infants showed a significant decrement in LWT across trials, suggesting that they habituated to the objects. Moreover, preliminary analyses showed that they also could discriminate between familiarization objects. These results suggest that human infants regarded the various familiarization objects as 'the same kind' and grouped them together. Thus, the human infants encoded some similarities between the objects that were repeatedly presented to them.

In the test phase, the human infants significantly preferred novel-category objects to novel familiar-category objects after being familiarized with mammals and furniture. This suggests the formation of categorical representations, at least for mammals and furniture. Global-like categorization, such as that found here, is consistent with previous reports concerning 1-year-old human infants (e.g. Mandler & McDonough, 1996).

After being familiarized with vehicles, however, infants did not show any novelty-preference. Although there may be several possible reasons for this – for example, vehicle exemplars might be more variable in appearance than mammal or furniture exemplars – we cannot single out any particular reason. It is noteworthy that this tendency was especially notable in the older infants.

It was frequently observed that older infants manipulated vehicles functionally; that is, they moved or slid the vehicle in a straight line; even though the vehicle wheels were fixed and immovable. These functional manipulations were also seen to a lesser extent in some younger infants, but not at all in chimpanzee infants. As the wheels were immovable, infants clearly did not learn to slide the vehicles through observing functional parts actually moving during the experiments. It is possible that they had prior knowledge about how to move vehicle exemplars. If so, infants might prefer to manipulate vehicles even after repeated presentations. To investigate this possibility, we assessed infants' specific manipulations in the test phases. Out of all 64 infants (32 younger infants and 32 older infants) who participated in the preference test and the category test, we counted the number of infants who produced two types of object manipulations from video records: sliding vehicles and making mammals hop. 'Sliding vehicle' was defined as moving the vehicle back and forth, not in one direction, more than once. 'Hopping mammal' was noted when the infant made mammals hop more than once. One of the two coders was blind to the aim and the hypothesis of the experiments. The concordance between the two coders was 95%; mismatches were resolved by a third person that was also blind to the aim and the hypothesis of the experiments.

Nineteen older infants performed sliding-vehicle, compared to 11 younger infants. Most importantly, out of eight older infants who were familiarized with vehicles, seven performed sliding-vehicle. In stark contrast, only one younger infant performed this movement in the same condition. It seems likely that repeated presentations of vehicle exemplars in the familiarization condition facilitated the sliding action in vehicle-familiarized older infants. In addition, in both age groups only two infants performed mammal-hopping actions. This indicates that, for human infants, scale models of vehicles afford sliding movements; this has been reported in some previous studies of human infants (e.g. Kosugi, Murai & Itakura, submitted; Rakison & Butterworth, 1998; Rakison & Cohen, 1999). Such manipulations of vehicles by infants do not depend on the specific context of the present study but on the infants' previous experiences and their understanding of object movement. This leads us to emphasize that the lack of novel-preference does not indicate that older infants failed to form a categorical representation of vehicles, because they clearly habituated to them in the familiarization phase.

Experiment 2 indicated that human infants showed significant habituation in the familiarization phase, and significant novelty-preference in the test phase, suggesting that they formed global-like categorical representations.

General discussion

The main result of the present study was that both human infants and chimpanzee infants could form categorical representations of three global-like categories (mammals, furniture and vehicles) that closely correspond to human adult global-level categories, without any training. This is the first report of global-like level categorization in chimpanzee infants. These findings also provide further evidence of spontaneous categorization by non-human primates in early development. Moreover, in combination with the previous results for infant macaques (Murai *et al.*, 2004), the present results indicate that non-human primate infants and human infants possess a similar disposition for object categorization. Thus, these results throw some light on the evolutionary origins of categorization in primates.

Studies of human infants' categorization have also focused on whether infants form categorical representations on-line during the course of familiarization trials within the task, or whether the experiments call up pre-existing categorical representations that were constructed on the basis of previous experiences with objects (e.g. Quinn, 2002). Given that infants could form categorical representations of stimulus objects presented in the tasks, even though they did not seem to have directly observed real exemplars (for instance, the real mammals such as tigers or giraffes), it seemed that their categorical representations were formed on-line, during the course of familiarization. However, as Quinn (2002) pointed out, it is also possible that infants have more experience with the test objects than we expect, through picture books or TV programs that depict exemplars of animals, vehicles and so on. Therefore, it would be difficult to determine whether prior experiences or the experiences derived from the familiarization trials drive the infants' performance in categorization experiments. However, the present study suggests that even chimpanzee infants can form categorical representations, although they undoubtedly possess few experiences of watching or manipulating objects from the human world. It seems likely that they did not rely on prior experience with the stimulus objects to form such categorical representations. In that context, the present findings contribute to the issue regarding category formation by human infants.

In the current study, it was found that chimpanzee infants at the ages of 10 to 23 months and human infants at the ages of 10 to 24 months showed a similar ability to form categorical representations. The performance by chimpanzee infants was found to be comparable to that of younger human infants (10–17 months), considering that younger human infants' LWTs were relatively shorter and their functional object manipulations were not frequent. This is consistent with Spinozzi *et al.*'s (1998; Spinozzi, 1993) finding that the development of sorting behavior in chimpanzee infants between the age of 15 and 54 months seems to be matching that of human infants between the age of 6 and 24 months. Thus, even though the ability to form categorical representation is shared between both species, the development of such ability in chimpanzees appears to be slower compared to that of human infants. In general, it is a rather complicated issue to compare the developmental rate between species. However, when comparing the physical development, for example, dentition, the developmental rate in chimpanzees is 1.5–2.0 times faster than that of humans (e.g. Takeshita, 1999). It is necessary to devise a cognitive measure as well as a physical one to compare development between species.

We must note that chimpanzee infants also showed some differences in their responses compared to human infants. The major difference was in the mode of familiarization.

Human infants' LWTs to objects decreased during familiarization; that is, they showed habituation. Thus, they seemed to recognize the familiarization objects as 'the same kind', and to group them together. In contrast, chimpanzee infants did not show clear familiarization. In Experiment 1, we described two possible reasons for these results: (1) the diversity among familiarization objects, and (2) the long inter-trial interval. In addition, another possibility is that the number of familiarization trials and the presentation time of each familiarization object might not be sufficient. In the current study, we conducted only four familiarization trials because it was difficult to keep chimpanzee infants focused on the experiment itself for a long time. We should conduct another experiment to examine these issues in the future. However, human infants showed significant habituation under the same familiarization condition as chimpanzee infants. Thus, it seems likely that this difference reflects some species differences in the cognitive capacity underlying categorization. We propose two possible differences.

First, chimpanzee infants may naturally differ from human infants in duration of object examination. As shown in Table 2 and Table 4, human infants' LWTs in the familiarization phase were much longer than those of chimpanzee infants. Human infants were likely to examine objects very carefully or slowly. Such careful object examination in human infants may make it easier for them to detect similarities among familiarization objects. On the other hand, the more rapid object examination of chimpanzee infants may make this more difficult. Alternatively, it is conceivable that chimpanzee infants' lack of familiarization was due to their shorter LWTs from the first trial.

Second, chimpanzee infants may differ from human infants in their level of object processing, as suggested by some recent studies. For instance, human infants show some flexibility in object processing, by attending not only to global but also to local properties of objects. Thus, very young infants may process object information at multiple levels, even when dealing with complex objects (e.g. Quinn, Bhatt, Brush, Grimes & Sharpnack, 2002). Object processing in human infants seems to result in them easily recognizing and integrating some similarities among objects. However, chimpanzees of all ages appear more likely to attend to local properties than global ones when processing objects (e.g. Fagot & Tomonaga, 1999). Therefore, given that our experiments concerned global-like categories, it might have been difficult for chimpanzee infants to view the familiarization objects as 'the same'.

Moreover, the shorter LWTs in chimpanzee infants probably imply that they processed only a limited subset of object properties. Young human infants tend to process objects by attending to particular parts, such as legs and/or internal facial features of animals, or wheels of vehicles (e.g. Quinn, 1998). They then gradually change to processing based on whole properties and correlations between parts of objects, at least by their second birthday (e.g. Rakison & Butterworth, 1998). It would be interesting to know whether there was a similar developmental change in chimpanzee infants; i.e. whether they would process whole objects in later development. Interestingly, Vonk and MacDonald (2002) reported that adults of another great ape, gorilla, recognize the abstract similarities among global category objects such as animals and non-animals, in the same–different task. Moreover, it is suggested that chimpanzees possess the capacity for object classification beyond the simple processing of identical properties of objects (e.g. Spinozzi, 1993, 1996). Thus, there is room for further investigation of whether chimpanzee infants are able to group objects or not.

In Experiment 2, it was observed that human infants manipulated objects functionally, that is, they slid vehicles as if to make their wheels turn. Such functional object manipulations indicate that, by 2 years of age, human infants may have developed certain kinds of knowledge about object characteristics such as object-appropriate movement (e.g. Mandler, 1992; Rakison & Cohen, 1999). Human infants seem to attend to object information beyond perceptual input, like expected movement, as well as visible information about objects, for example, their features. Such expectations may play an important role in forming some categories that are thought of as conceptual, like 'animal'.

Contrary to human infants, chimpanzee infants did not show the functional object manipulation. For now, as far as we know, there is no research investigating whether chimpanzees would associate certain objects with certain kinds of movement. Besides, it would appear that chimpanzee infants predominantly explore objects orally rather than visually and manually in this developmental period. Human infants tend to explore objects with their mouth in early development, and then they gradually develop manual and visual inspection (see Rochat, 2001). It is important to track the development of manual examination and visual inspection in chimpanzee infants, given the implications for later ability to process invisible or abstract object properties such as function and biological structure.

In the present study, we directly compared the categorization ability of chimpanzee infants and human infants through two experiments. These experiments revealed important similarities and differences in early categorical behaviors between two closely related species. These results suggest that both species may share the fundamentals of categorical representation, while they seem to have developed species-specific categorization capacities during evolution. The current results also raise some further questions. How and when does categorization ability further develop in chimpanzees? Do chimpanzee infants develop basic-level categorization as reported in human infants or not? Do they form conceptual categories as seen in human children and adults or not? What kind of cognitive ability is associated with the development of categorization in chimpanzees? The study of such questions will provide a fuller understanding of the nature of human categorization. Future work will examine whether chimpanzee infants form categorical representations of basic- and more comprehensive level categories.

Acknowledgements

We thank Hiraku Ishida, Junko Matsumoto and the staff of the Language and Intelligence Section and Center for Human Evolution Modeling Research of the Primate Research Institute for their support throughout the research. We also thank Dr James R. Anderson for his editing of and comments on the earlier version of the manuscript. This study was supported by Ministry of Education, Culture, Sports, Science and Technology, Japan, Grant-in-Aid for the 21st Century COE Program (D-2 to Kyoto University), for Scientific Research #12002009, 16002001 JSPS-HOPE and the Cooperative Research Program of the Primate Research Institute, Kyoto University.

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Received: 15 December 2003
Accepted: 4 June 2004