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Distinct Processing for Pictures of Animals and Objects: Evidence From Eye Movements

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Many studies have suggested that emotional stimuli orient and engage attention. There is also evidence that animate stimuli, such as those from humans and animals, cause attentional bias. However, categorical and emotional factors are usually mixed, and it is unclear to what extent human context influences attentional allocation. To address this issue, we tracked participants' eye movements while they viewed pictures with animals and inanimate images (i.e., category) as focal objects. These pictures had either negative or neutral emotional valence, and either human body parts or nonhuman parts were near the focal objects (i.e., context). The picture's valence, arousal, position, size, and most of the low-level visual features were matched across categories. The results showed that nonhuman animals were more likely to be attended to and to be attended to for longer times than inanimate objects. The same pattern held for the human contexts (vs. nonhuman contexts). The effects of emotional valence, category, and context interacted. Specifically, in images with a negative valence, focal animals and objects with human context had comparable numbers of gaze fixations and gaze duration. These results highlighted the attentional bias to animate parts of a picture and clarified that the effects of category, valence, and picture context interacted to influence attentional allocation.

Keywords: emotion, category, attention, eye-tracking

Many studies have shown that emotional stimuli are processed more quickly and efficiently than neutral stimuli and can increase vigilance in dangerous situations. Emotional stimuli facilitate attention and perception by feedback from the amygdala to perceptual regions (Amaral, 2003; Davis & Whalen, 2001; Phelps, 2006; Phelps & LeDoux, 2005; Whalen, 1998). The relationship between emotion and attention has been investigated using different behavioral paradigms and eye-tracking techniques (Hermans, Vansteenwegen, & Eelen, 1999; Mogg & Bradley, 1999; Öhman, Flykt, & Esteves, 2001; Öhman, Lundqvist, & Esteves, 2001; Tipples, Young, Quinlan, Broks, & Ellis, 2002). For example, in a dot-probe task, after two pictures were presented simultaneously, a dot probe replaced one of them. Participants detected the dot more quickly if it was presented in the place where an emotional, instead of a neutral, stimulus was placed (Mogg & Bradley, 1999). Eye movements are usually coupled with attentional shift (Rayner, 1998; Henderson, 2003; Henderson & Hollingworth, 1999; Hermans et al., 1999; Martinez-Conde, Macknik, & Hubel, 2004); thus, they have been identified as an overt behavioral index of attention (Henderson, 2003). An advantage of this index is that eye movements can be recorded over time, and the initial orienting period can be separated from the subsequent engagements.

Eye-tracking studies have confirmed that emotional pictures facilitate both attentional orienting and engagement. In simultaneous matching tasks, participants were asked either to compare pleasantness of pictures (Calvo & Lang, 2004; Nummenmaa, Hyönä, & Calvo, 2006) or to avoid looking at emotional pictures (Nummenmaa et al., 2006). The results showed that, in both tasks, participants were more likely to first fixate (within 500 ms) longer on emotional pictures than on neutral pictures. In addition, emotional scenes are processed more efficiently because a shorter fixation time was required for participants to accurately identify emotional pictures, although the number of fixations was higher for emotional pictures than it was for neutral pictures (Calvo, Nummenmaa, & Hyönä, 2007). Moreover, coarse information about an emotional scene is sufficient for covert attentional bias. After a picture has been fixated on, semantic factors begin to influence the saliency map (Calvo, Nummenmaa & Hyönä, 2008),

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and semantic information can be extracted even without identification of individual objects in the scene (Calvo et al., 2008; Gordon, 2004).

However, there is some debate over which features account for increased attention to emotional stimuli. Some researchers have proposed that attentional bias occurs toward negative and especially threatening stimuli, and that uncertainty of danger enhances vigilance level (Bannerman, Milders, de Gelder, & Sahraie, 2009; Bradley, Mogg, & Millar, 2000). Others have proposed that arousal dimension is more important for attracting attention because participants have similar eye movement patterns when viewing negative and positive pictures (Calvo & Lang, 2004; Nummenmaa et al., 2006; Schimmack, 2005; but see Bradley et al., 2000). On the other hand, stimulus category is an important but often neglected factor in emotional processing. As proposed by the preparedness model (Seligman, 1970; Öhman & Mineka, 2001), stimuli related to survival threats in evolutionary history are preferentially activated. Thus, fear is more readily learned and more resistant to extinction for stimuli related to threats experienced by our evolutionary ancestors (e.g., snakes, spiders) than for stimuli that have recently emerged in our cultural history (e.g., guns, motorcycles).

Studies have found that animate stimuli (e.g., animals, human faces) attract more attention than inanimate stimuli. The response time was shorter when snakes or spiders served as targets and flowers or mushrooms served as distracters than the other way around (Öhman, Flykt, & Esteves, 2001, Öhman, Lundqvist, & Esteves, 2001; but see Brosch & Sharma, 2005). On the other hand, the attentional bias to animate stimuli may not be limited to fearful stimuli because animal targets, whether fearful or neutral, were detected more quickly than inanimate targets (Lipp, Derakshan, Waters, & Logies, 2004). In a recent study using a detection task, participants detected changes to humans and inanimate animals more quickly and accurately than changes to inanimate objects (New, Cosmides, & Tooby, 2007). These results suggested that animate stimuli attract more attention than inanimate objects because identifying potential dangerous stimuli quickly is important for human ancestors to survival (animate monitoring hypothesis, New et al., 2007). However, previous studies did not separate the effects of emotion and stimulus category in attentional bias. For example, in the simultaneous detection task (Calvo & Lang, 2004; Nummenmaa et al., 2006), the emotional dimension always depicts people, whereas the neutral one always depicts inanimate objects. So the two stimuli differ not only in emotional valence but also in stimulus category, and it is unclear whether more fixations and longer gazes for one stimulus result from emotional difference or category difference. New et al. (2007) found category-selective attention for animals, but they did not mention the emotional features of these pictures, which leaves open whether category-specific selection is related to emotional features (Öhman, 2007).

In summary, previous studies have explored either the relationship between emotion and attention or the relationship between category and attention, but few have explored the three-way relationship among category, emotion, and attention. It has been found that nonhuman animals and inanimate objects induce differential activation along the ventral and lateral visual brain regions (Chao, Haxby, & Martin, 1999; for review, see Martin, 2007). One recent study showed that humans and nonhuman animals elicited stronger activation than inanimate objects in the amygdala (Yang, Bellgowan, & Martin, 2011). Because stronger activation of the amygdala could facilitate attention via increased activation in the ventral and lateral visual regions by feedback projections (Amaral, 2003; Phelps & LeDoux, 2005; Whalen, 1998), we hypothesized that emotional and categorical factors interact with each other to influence attentional allocation.

Another important factor is whether humans or human body parts are included in the picture. Participants can use the contextual human information to make inferences about the intentions of conspecifics (Norris, Chen, Zhu, Small, & Cacioppo, 2004). For example, people may attend to and react differently when they see a gun on a table versus a gun handled by a human hand, the latter indicating the potential presence of a threatening situation and may evoke strong emotional and attentional responses. Recent studies have also shown that pictures involving humans, human faces, biological movement, or social scenes lead to stronger activations in the amygdala, ventral temporal gyrus (e.g., fusiform faces area), and superior temporal sulcus (for reviews, see Adolphs, 2009, 2010; Phelps, 2006). Human or human-related information has been shown to influence eye movements (Ferreira, Apel, & Henderson, 2008; Neider & Zelinksy, 2006; Torralba, Oliva, Castelhano, & Henderson, 2006). Thus, human context can interact with focal object in a picture to modulate attentional allocation. Emotional pictures with human context may be more likely attended to and be attended to for longer time.

To identify relationships among category, emotion, and contextual information in attentional processing, we used an eye-tracking technique while participants viewing negative and neutral pictures. These pictures contained nonhuman animals or inanimate objects with either human or nonhuman parts. Valence and arousal levels were matched across categories to distinguish effects of category and emotion. Because lower-level visual features (e.g., luminance, contrast, color) and factors of familiarity and complexity influence eye movements (Henderson, 2003; Rayner, 2009), they were matched across categories and analyzed as well. Because both trait and state anxiety levels influence attentional orienting and engagement (Bradley, Mogg, Falla, & Hamilton, 1998; Bradley et al., 2000), participants were measured by the State-Trait Anxiety Inventory (STAI) (Spielberger, 1983) to ensure that they had no obvious change of status anxiety due to the experiment. Based on previous studies, we predicted that animate features, including both nonhuman animals and nearby human contexts, attract more attention in both orienting and engagement. In addition, category interacts with contextual information, in that negative animals and inanimate objects receive comparable attention when humans (or human parts) are included in the context.

Method

Participants

Sixty-seven right-handed, healthy students from Peking University participated in the study (31 men, 36 women; $M_{age} = 22.11$ years, $SD = 1.81$). They were native Chinese speakers with normal or corrected-to-normal vision and without any history of neurological or psychiatric disorders. Of these participants, 20 participated in emotional rating (nine men), 13 participated in familiarity and complexity ratings (seven men), and 34 participated in the eye-tracking experiment (15 men). There were no significant differences in age, $F(2,56) = .37$, $p > .60$, or sex, $\chi^2 = .15$, $p > .90$, among the three groups. All participants were paid for their participation, and all gave written consent in accordance with the procedures and protocols approved by the institutional review board of the Department of Psychology, Peking University.

Design and Materials

Three within-subject factors were included in the eye-tracking experiment, emotional valence (negative, neutral), category (nonhuman animals, inanimate objects), and context (with or without human parts). The combination of the three factors made up eight experimental conditions, as demonstrated in Figure 1. The stimuli in the eye-tracking experiment consisted of 240 colorful, nameable experimental pictures (30 per condition) as well as 40 filler pictures (e.g., outdoor neutral scenes) with a resolution of 1024 × 768 pixels. The pictures represented 31 concepts: eight negative (e.g., spider, snake) and seven neutral (e.g., cow, sheep) nonhuman animal concepts; eight negative (e.g., gun, syringe) and eight neutral (e.g., hammer, wrench) inanimate object concepts (see Appendix). Each concept was presented in contexts with and without human (or human parts). The orientation of the stimuli was matched across conditions. Three areas of interests (AOIs) were defined for each picture: the focal object was defined as the discrete entity located in the picture (Henderson & Hollingworth, 1999), the context was defined as the part near the focal object, and the background was defined as the part beyond the focal object and context.

Picture selection was based on the results from the valence and arousal rating group and familiarity and complexity rating group. Low-level visual features, picture size, and position of focal object and context were also analyzed and mostly matched across categories.

Emotional rating. Participants were asked to evaluate each picture's valence (1 = *very unpleasant* to 9 = *very pleasant*) and arousal (1 = *very calming* to 9 = *very arousing*). For the selected 240 pictures, negative pictures were lower in valence, $F(1, 18) = 289.6$, $p < .001$, partial $\eta^2 = .94$, and higher in arousal scores, $F(1, 18) = 119.3$, $p < .001$, partial $\eta^2 = .87$, than the neutral pictures. Pictures with human contexts were lower in valence, $F(1, 18) = 54.47$, $p < .001$, partial $\eta^2 = .75$, and higher in their arousal scores, $F(1, 18) = 84.22$, $p < .001$, partial $\eta^2 = .82$, than those without human contexts. However, pictures of nonhuman animals and objects were comparable in their valence, $F(1, 18) = 0.47$, $p > .500$, partial $\eta^2 = .03$, and their arousal, $F(1, 18) = 4.11$, $p > .058$, partial $\eta^2 = .19$, scores. Although the interaction between category and context was significant in both valence, $F(1, 18) = 7.11$, $p < .016$, partial $\eta^2 = .28$, and arousal, $F(1, 18) = 4.56$, $p < .047$, partial $\eta^2 = .20$, nonhuman animals only showed higher arousal scores than inanimate objects without human contexts. No other significant interactions were found related to category, $ps > .1$. These results suggested that the nonhuman animals and inanimate objects are optimally matched in their affective features (see Table 1).

Familiarity and complexity ratings. Participants evaluated familiarity by rating how often they saw or thought of the focal object (i.e., an animal or object) or the context in their daily life (1 = *least familiar* to 7 = *most familiar*). For the focal objects (see Table 1), there were no significant main effects of context, $F(1, 12) = 2.89$, $p > .110$, partial $\eta^2 = .19$, or category, $F(1, 12) = 2.77$, $p > .120$, partial $\eta^2 = .19$. Negative pictures were less familiar than neutral pictures, $F(1, 12) = 13.71$, $p < .003$, partial $\eta^2 = .53$. The significant interaction between valence and category, $F(1, 12) = 6.27$, $p < .028$, partial $\eta^2 = .34$, indicated that negative animal pictures were less familiar than negative objects, $p < .001$. Human contexts were more familiar than the contexts without human (or human parts), $F(1, 12) = 52.55$, $p < .001$, partial $\eta^2 = .81$. The human contexts in negative pictures were less familiar than those in the neutral pictures, $F(1, 12) = 122.72$, $p < .001$, partial $\eta^2 = .91$. There were no significant effects of category and other interactions, $p > .1$.

In the complexity rating, participants rated the degree of details in a picture and the degree of changes on its contours (1 = *least complex* to 7 = *most complex*). For the focal objects (see Table 1), because colored pictures were used, it is conceivable that the animal pictures were rated more complex than the objects, $F(1, 12) = 37.64$, $p < .001$, partial $\eta^2 = .76$, and pictures with human contexts were marginally more complex than those without human contexts, $F(1, 12) = 4.31$, $p = .060$, partial $\eta^2 = .26$. Human contexts were rated more complex than

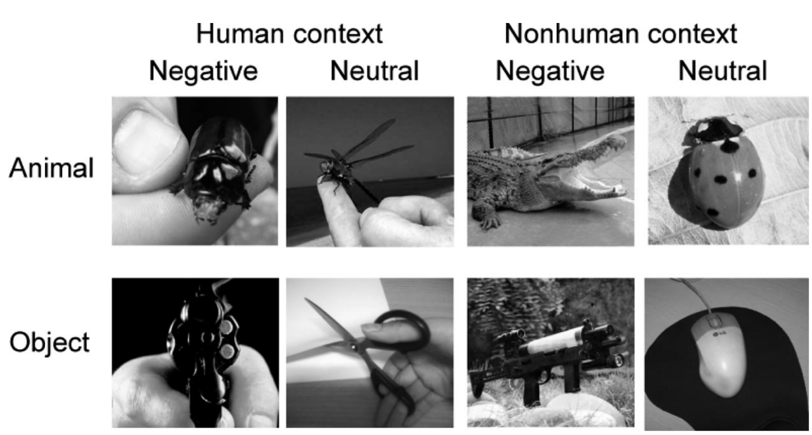

Figure 1. Stimulus examples.

Table 1
Rating Results Under Different Conditions

	Human context				Nonhuman context			
	Negative		Neutral		Negative		Neutral	
Condition	Animal	Object	Animal	Object	Animal	Object	Animal	Object
Valence								
M	2.89	2.87	4.83	4.81	3.34	3.74	4.92	5.03
SD	0.83	0.58	0.84	0.41	0.81	0.82	1.02	0.38
Arousal								
M	6.88	6.70	4.55	4.23	6.26	5.73	4.19	3.86
SD	0.77	0.78	1.16	1.35	0.83	0.97	1.12	1.40
Familiarity								
M	3.38*	4.17	4.47	4.24	3.48*	4.06	4.51	4.52
SD	1.03	1.06	1.35	0.51	1.07	1.07	1.36	0.47
Complexity								
M	4.95*	3.57	4.67*	3.86	5.00*	3.61	4.88*	3.88
SD	0.78	0.65	0.79	0.71	0.66	0.77	0.79	0.70

* Denotes significant difference between animals and inanimate objects ($p < .05$).

nonhuman contexts, $F(1, 12) = 20.4$, $p < .001$, partial $\eta^2 = .63$, and contexts of nonhuman animals were more complex than those of inanimate objects, $F(1, 12) = 6.58$, $p < .025$, partial $\eta^2 = .35$.

Low-level visual features. We matched low-level visual features across categories, including luminance, contrast, saturation of each color channel (red, green, blue), as well as pixel intensity skewness, kurtosis, and power of focal object (see Table 2) and its context within a picture. These features were calculated using a Matlab program (The MathWorks). The average luminance values of each picture were computed by transferring a color picture from RGB space to YUV space and by calculating the value of Y component. The mean contrast level of each picture was measured with root mean square contrast (Bex & Makous, 2002). Color saturation for the red, green, and blue channels was obtained by computing the mean value of each channel in a color image. Pixel intensity skewness and kurtosis were computed from the distribution of pixel intensity values after a color picture was changed to a gray image. The value of power was obtained by calculating frequency spectrum in Fourier analysis for each picture.

The analysis of variance (ANOVA) with category, valence, and context as factors showed no significant category effects or

Table 2
Visual Features of Focal Objects Under Different Conditions

	Human context				Nonhuman context			
	Negative		Neutral		Negative		Neutral	
Condition	Animal	Object	Animal	Object	Animal	Object	Animal	Object
Luminance	92.28	108.89	96.05	101.45	108.05	105.96	112.34	97.97
	42.30	42.13	25.27	28.34	55.77	34.11	52.19	44.99
RMS	0.17	0.19	0.18	0.20	0.19	0.20	0.20	0.21
	0.07	0.05	0.06	0.05	0.06	0.07	0.07	0.06
Red	95.37	124.47	109.04	118.78	119.70	107.91	117.30	105.95
	43.93	42.86	32.24	34.02	54.12	36.79	52.61	47.45
Green	92.64	104.70	92.64	98.00	104.33	105.85	110.27	94.88
	46.16	43.78	25.60	32.12	57.81	36.25	53.16	47.06
Blue	82.33	89.52	79.54	73.74	96.60	101.39	110.02	92.94
	46.45	41.97	28.40	35.77	58.46	35.04	53.77	50.57
Skewness	1.81	1.20	1.03	0.91	3.09	1.83	2.65	2.67
	2.00	1.01	1.16	0.89	3.72	1.64	2.95	2.12
Kurtosis	10.63	4.98	4.50	4.03	27.42	9.44	20.45	15.92
	17.98	4.20	8.23	3.02	59.28	17.11	41.21	23.80
Power	$5.01*10^{14}$	$5.72*10^{14}$	$8.14*10^{14}$	$8.53*10^{14}$	$3.39*10^{14}$	$4.39*10^{14}$	$7.54*10^{14}$	$6.28*10^{14}$
	$3.57*10^{14}$	$4.71*10^{14}$	$5.98*10^{14}$	$6.27*10^{14}$	$3.23*10^{14}$	$3.71*10^{14}$	$5.01*10^{14}$	$4.77*10^{14}$
Saliency	0.36*	0.24	0.34	0.29	0.36	0.32	0.24*	0.35
	0.15	0.13	0.14	0.13	0.15	0.15	0.15	0.15

Note. RMS = root mean square.
* Denotes significant difference between animals and inanimate objects ($p < .05$).

category-related interactions for visual luminance, contrast, saturation of each color channel, pixel intensity skewness, or kurtosis for both focal objects, Fs < 3, $p > .05$, and contexts, Fs < 3, $p > .05$. Only the picture power of focal objects showed significant interactions of category by valence, $F(1, 239) = 36.13$, $p < .001$, partial $\eta^2 = .14$, and category by context, $F(1, 239) = 9.95$, $p < .002$, partial $\eta^2 = .05$. The power of nonhuman animals was significantly smaller than that of inanimate objects under negative and human-context conditions, but significantly larger under neutral and context without human conditions, ps $< .05$. Also no significant differences were found for simple contrasts between animals and objects (see Table 2). The power of focal objects was smaller than the contexts, $t(239) = 2.0$, $p < .047$.

At the same time, we measured the visual saliency of each image with the computational saliency models proposed by Itti and Koch (2001) and Wang, Wang, Huang, and Gao (2010). A saliency map quantitatively shows the degree of conspicuity at each location in an image (Itti & Koch, 2001; Parkhurst, Law, & Niebur, 2002). Low-level visual features such as color, intensity, and orientation are involved in generating visual salience in a picture (Henderson, 2003; Parkhurst et al., 2002). Because there were similar results with the two models, the results by Wang et al. (2010) are reported here. The focal objects were significantly more salient than the contexts of the pictures, $t(239) = 10.19$, $p < .001$. For focal objects, there were significant interactions of Category × Valence, $F(1, 239) = 8.72$, $p < .003$, partial $\eta^2 = .04$, and Category × Context, $F(1, 239) = 10.67$, $p < .001$, partial $\eta^2 = .04$. This showed that nonhuman animals were more salient than inanimate objects, especially under negative and human-context condition.

Other factors. The size and position for focal objects, Fs < 3, $p > .1$, $\chi^2 = 26.04$, $p > .3$, and contexts, Fs < 3, $p > .1$, $\chi^2 = 26.04$, $p > .9$, were not significantly different across eight conditions. In addition, size did not differ significantly between the focal object and context in a given picture, $t(239) = .55$, $p > .5$. These results are important because they indicate that factors of size and position should not confound the eye-movement patterns (Chua, Boland, & Nisbett, 2005).

Eye-Tracking Apparatus

Stimuli were presented on a 17-in. ViewSonic monitor with a resolution of 1024 × 768 pixels. Participants sat on a chair and placed their head on a chin rest so that their heads were 60 cm away from the viewing screen. Eye movements were monitored using a SensoMotoric Instruments eye-tracker connected to a computer with a sampling rate of 500 Hz. Participants viewed the pictures binocularly, but only their right eye movements were monitored. The eye-tracker was calibrated prior to picture presentation using the 9-point matrix. Recalibration was performed between blocks.

Eye-Tracking Experiment Procedure

At the beginning of each trial, a fixation "+" was presented for 2 s and then a picture was shown for 3 s. Participants were asked to look at the picture. After that, a sentence related to the picture (60%) or a blank screen (40%) was presented for 5 s. When the sentence was presented, participants were asked to judge whether it described the picture correctly. Half of the sentences were true and half were false. In addition, each sentences described the focal object, context, or background part of the picture. The veracity of the sentence and the part of the description were counterbalanced across conditions. A blank screen was shown randomly to prevent participants from adopting a strategy of viewing the picture in a specific order. To avoid the induction of long-lasting mood states, the 240 pictures and 40 filler pictures were pseudorandomized so that no more than three pictures with the same valence level were presented consecutively. All pictures were grouped into four blocks, and the order of blocks was counterbalanced across participants. A practice session was conducted with each participant to get him or her familiar with the task before the experiment. Each also filled out the STAI (Spielberger, 1983) before and after the test.

Data Analysis

Participants correctly answered 75% (SD = 11%) of the comprehensive questions in the sentence task. Data from nine participants were excluded from analysis due to calibration failure (four participants), tracker errors (four participants), and withdrawal from the study (one participant). The statistical analyses reported below were computed on the basis of the remaining 25 participants (13 men, 12 women).

Attention dynamics are a function of both fixation location and fixation duration (Henderson, 2003), so the eye-tracking parameters included gaze duration, the number of gaze fixations, and the duration and probability of the first fixation (Chua et al., 2005; Calvo & Lang, 2004; Nummenmaa et al., 2006). Among the parameters, gaze duration refers to the summed duration of fixations made on any of the AOIs when looking at it for the first time before looking away from it (Henderson, 2003). Thus, the gaze duration and the number of fixations reflect how long participants attended to certain regions in a picture. The duration and probability of the first fixation reflects attentional orienting to each part of a picture at the beginning of each trial. We also analyzed the data of total number of fixations and total fixation duration, but they are not reported because they were very similar to those of the number of gaze fixations and gaze duration. The repeated-measures ANOVAs were conducted with context, valence, and category as factors for focal objects and contextual AOIs, separately, $p < .05$, two-tailed.

To analyze the effects of other factors on eye movement parameters, we adopted a covariate ANOVA and a stepwise multiple regression. The factors of context, valence, and category were included in the covariate ANOVA, with other factors were defined as control factors. In the stepwise multiple regression, the category and other factors were entered into the regression at Steps 1 or 2 separately, with eye-movement parameters as dependent variables. The changes of R and the corresponding F values were used as indexes of each factor's contribution to the eye-movement patterns, $p < .05$.

Results

Gaze Fixation Analysis

Gaze duration. Eye movements differed for the focal object and contextual part of the picture. Participants looked longer at the focal objects than at the contexts (687 ms vs. 271 ms), $F(2, 48) = 55.22$, $p < .001$, partial $\eta^2 = .71$. For the focal object AOIs, participants attended to nonhuman animals longer than they did to the inanimate objects (758 ms vs. 616 ms), $F(1, 24) = 59.01$, $p < .001$, partial $\eta^2 = .71$. This category effect was significant for pictures whether or not the context was human, $ps < .001$, but was smaller for pictures with human contexts. It is important to note that there was a significant interaction among context, valence, and category, $F(1, 24) = 20.24$, $p < .001$, partial $\eta^2 = .46$, showing that negative nonhuman animals and negative objects were fixated on for comparable duration in the context of human parts, $p > .25$ (Figure 2, left).

Focal objects with human contexts were attended to for shorter durations (553 ms vs. 820 ms), $F(1, 24) = 145.09$, $p < .001$, partial $\eta^2 = .86$, but human contexts were attended to for longer durations than nonhuman contexts (332 ms vs. 210 ms), $F(1, 24) = 100.98$, $p < .001$, partial $\eta^2 = .81$ (see Figure 2, right), especially for those of negative and animal pictures (Context × Valence), $F(1, 24) = 29.03$, $p < .001$, partial η2 = .55; (Context × Category), $F(1, 24) = 7.80$, $p < .001$, partial $\eta^2 = .25$. The contexts of inanimate objects were attended to longer than those of nonhuman animals, $F(1, 24) = 54.12$, $p < .001$, partial $\eta^2 = .69$, especially for negative pictures, $F(1, 24) = 10.43$, $p < .001$, partial $\eta^2 = .30$, suggesting that participants allocated more attention to potential threats. In addition, although the main effect of valence was not significant for focal objects (677 ms vs. 697 ms), $F(1, 24) = 2.76$, $p > .110$, partial $\eta^2 = .10$, the contexts of negative pictures were attended to longer than those of neutral pictures, $F(1, 24) = 106.51$, $p < .001$, partial $\eta^2 = .82$.

Number of gaze fixations. The results of the number of gaze fixations were similar to those of gaze duration. There were more gaze fixations on the focal object than on the context (2.46 vs. 1.1), $F(2, 48) = 15.20$, $p < .001$, partial $\eta^2 = .40$. For the focal object AOIs, nonhuman animals were attended to more than objects (2.65 vs. 2.27), $F(1, 24) = 46.36$, $p < .001$, partial $\eta^2 = .66$. This category effect was significant for pictures whether or not the context was human, $ps < .001$, but was smaller for pictures with human contexts. The category effect disappeared when negative animals and negative objects with human parts were compared, $p > .79$ (Figure 3, left). This significant interaction among category, valence, and context, $F(1, 24) = 19.24$, $p < .001$, partial $\eta^2 = .45$, suggests that when the context contains human or human parts, the degree of attention to negative objects is comparable to that of negative animals. The main effect of valence was not significant (2.27 vs. 2.43), $F(1, 24) = 1.79$, $p > .19$, partial $\eta^2 = .07$, suggesting that negative focal objects were attended to at a level comparable to that of neutral pictures.

Again, the focal objects with human context received less attention (1.98 vs. 2.94), $F(1, 24) = 213.98$, $p < .001$, partial $\eta^2 = .90$. This is because participants allocated more attention to the human contexts than to the contexts without humans (or human parts) (1.35 vs. 0.86), $F(1, 24) = 118.64$, $p < .001$, partial $\eta^2 = .83$ (see Figure 3, right), especially in negative and animal pictures (Context × Valence), $F(1, 24) = 31.54$, $p < .001$, partial $\eta^2 = .57$; (Context × Category), $F(1, 24) = 14.08$, $p < .0001$, partial $\eta^2 = .37$. The contexts of inanimate objects were attended to more than those of nonhuman animals, $F(1, 24) = 56.28$, $p < .001$, partial $\eta^2 = .70$, especially for negative pictures (category by valence), $F(1, 24) = 11.44$, $p < .01$, partial $\eta^2 = .32$. In addition, the contexts of negative pictures were attended to more than those of neutral pictures, $F(1, 24) = 119.91$, $p < .001$, partial $\eta^2 = .83$.

First Fixation Analysis

First fixation duration. The first fixation duration was longer when it was located on the focal object than on the context (260 ms vs. 166 ms), $F(2, 48) = 48.72$, $p < .001$, partial $\eta^2 = .67$. When the first fixation was located on the focal object AOI, category effect appeared, showing that nonhuman animals were attended longer than inanimate objects (270 ms vs. 250 ms), $F(1, 24) = 12.87$, $p < .001$, partial $\eta^2 = .35$. Unlike the gaze duration, there was a significant interaction between category and valence, $F(1, 24) = 8.05$, $p < .01$, partial $\eta^2 = .25$, because the category effect was significant only for negative pictures, $p < .02$, (Figure 4, left), and negative focal objects were fixated on longer than neutral only for the animal pictures, $p < .02$. The main effect of context and other interactions were not significant, $ps > .1$. When the first fixation was located on the context (see Figure 4, right),

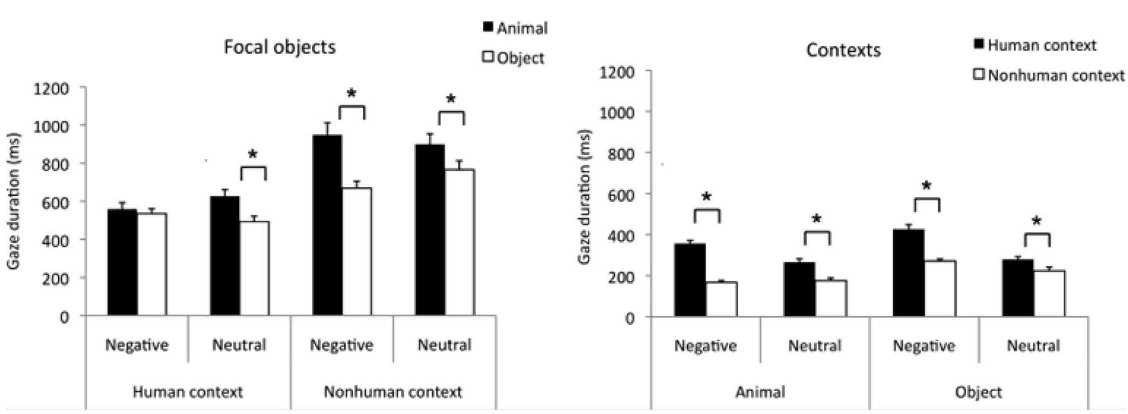

Figure 2. Gaze durations. For the focal object area of interest, nonhuman animals were attended to for a longer period of time than inanimate objects, except for the negative pictures with human contexts. The human contexts were attended to for a longer period of time than the nonhuman contexts. * Denotes significant difference ($p < .05$) between nonhuman animals and inanimate objects. Error bars represent the standard error of mean.

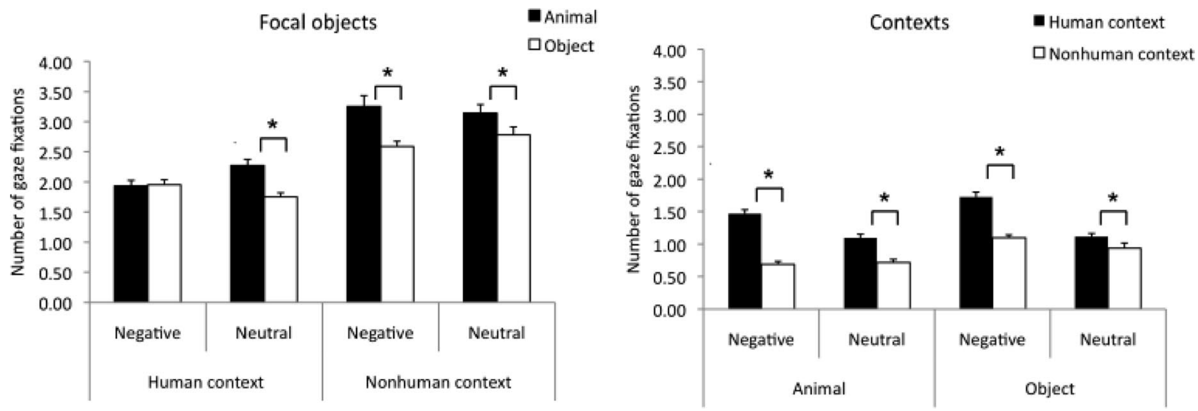

Figure 3. Number of gaze fixations. For the focal object area of interest (AOI), nonhuman animals were attended to more than inanimate objects, except for the negative pictures with human contexts. For the context AOI, the human contexts were attended to more than the contexts without human or human parts. * Denotes significant difference ($p < .05$) between nonhuman animals and inanimate objects. Error bars represent the standard error of mean.

human parts were attended to for a longer period of time than nonhuman parts (190 ms vs. 142 ms), $F(1, 24) = 73.94$, $p < .001$, partial $\eta^2 = .75$. The context of negative pictures was attended to longer than that of neutral pictures (177 ms vs. 156 ms), $F(1, 24) = 16.89$, $p < .001$, partial $\eta^2 = .41$, and the context of inanimate objects was attended to longer than that of nonhuman animals (174 ms vs. 159 ms), $F(1, 24) = 13.27$, $p < .001$, partial $\eta^2 = .36$.

First fixation probability. The focal objects were more likely to be fixated on than the contexts (0.52 and 0.17), $F(2, 48) = 86.42$, $p < .001$, partial $\eta^2 = .78$. Animal focal objects were more likely to be fixated on than the inanimate objects (0.57 vs. 0.46), $F(1, 24) = 74.1$, $p < .001$, partial $\eta^2 = .76$, and focal objects without human parts were more likely to be attended to than those with human parts (0.63 vs. 0.40), $F(1, 24) = 334.76$, $p < .001$, partial $\eta^2 = .93$. The significant interaction between category and context, $F(1, 24) = 27.06$, $p < .01$, partial $\eta^2 = .53$, indicated that the category effect was smaller for focal objects with human contexts than for those without human contexts, ps $< .05$ (Figure 5, left). Because the size and position of focal objects were comparable, the difference in the probability of first fixation was not confounded by either factor. When the first fixation was located on the context, human parts were more attended to than nonhuman parts (0.23 vs. 0.10), $F(1, 24) = 192.89$, $p < .001$, partial $\eta^2 = .89$ (see Figure 5, right). The context of negative pictures was attended to more than that of neutral pictures (0.20 vs. 0.13), $F(1, 24) = 128.92$, $p < .001$, partial $\eta^2 = .84$, and the context of inanimate objects was attended to more than that of nonhuman animals (0.19 vs. 0.14), $F(1, 24) = 34.83$, $p < .001$, partial $\eta^2 = .62$.

Control for Familiarity, Complexity, and Visual Features

Although there were significant category-related effects for the picture's familiarity and complexity ratings, the ANOVA (with them as covariates) and multiple regression analysis indicated that

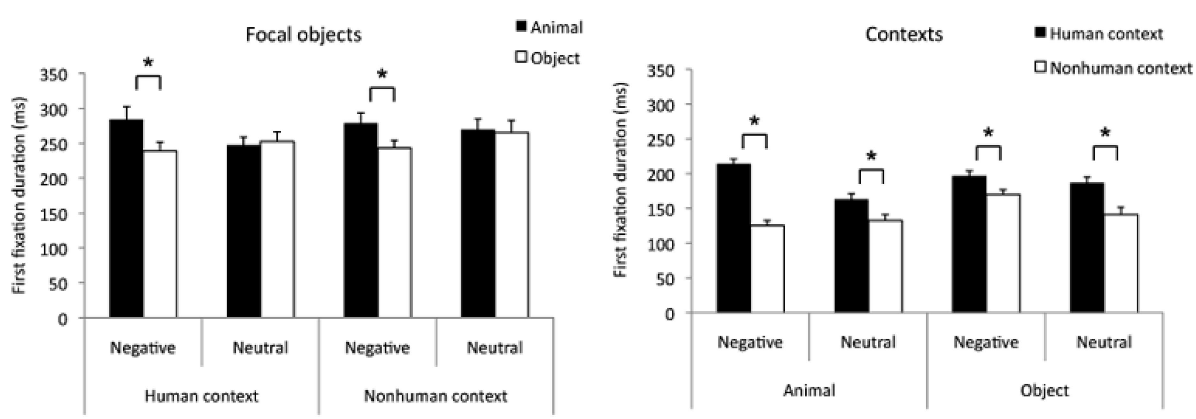

Figure 4. Duration of the first fixation. Nonhuman animals were attended to for a longer period of time than objects only for the negative pictures. The human contexts were attended to for a longer period of time than the nonhuman contexts. * Denotes significant difference ($p < .05$) between nonhuman animals and inanimate objects. Error bars represent the standard error of mean.

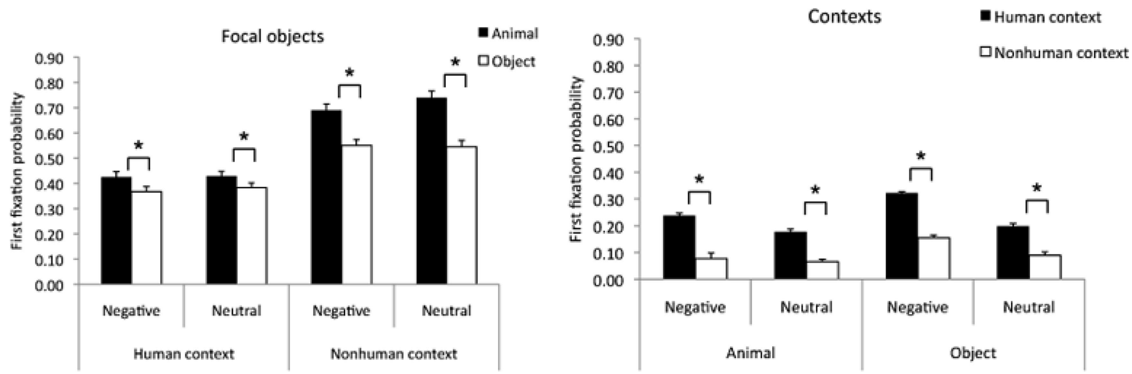

Figure 5. Probability of the first fixation. Nonhuman animals were more likely to be attended than the inanimate objects. The human contexts were attended to more than the contexts without human or human parts. * Denotes significant difference ($p < .05$) between nonhuman animals and inanimate objects. Error bars represent the standard error of mean.

these factors were not the determinants that influenced eye-movement results. There were significant effects of category for the eye-movement parameters when familiarity or complexity was included as a covariate, $F\text{s} > 4$, $p < .05$. In the stepwise multiple regression, adding familiarity or complexity at Step 2 significantly increased R scores, $p\text{s} < .05$, but the F changes were smaller than adding category at Step 2 for all parameters, $p\text{s} < .05$. This suggested that category is more important to determining eye-movement parameters. Take gaze duration as an example, adding familiarity at Step 2 increased R from 0.44 to 0.51, F change $= 20.28$, $p < .001$, but adding the factor category at Step 2 increased R significantly from 0.24 to 0.51, F change $= 54.21$, $p < .001$. For the complexity rating, adding complexity at Step 2 increased R from 0.45 to 0.54, F change $= 31.74$, $p < .001$, but adding category at Step 2 increased R significantly from 0.38 to 0.54, F change $= 49.45$, $p < .001$.

Similarly, there were significant category-related effects for picture power and saliency values for focal objects, but the ANOVAs with power or saliency as the covariate and the multiple regression analysis indicated that these factors do not influence eye-movement results. The covariate results revealed significant category effects for the number of gaze fixations, gaze duration, duration, and probability of the first fixation, $F\text{s} > 4$, $p < .05$, but there were no significant effects on picture power and saliency for eye-movement parameters, $F\text{s} < 2$, $p > .1$. Adding power or saliency into the multiple regression analysis did not significantly increase R values for any of the eye-movement parameters, $p\text{s} > .2$. In addition, although the focal objects had significantly lower power values and larger saliency values than the contexts, the ANOVAs with power or saliency as a covariate did not influence the pattern of more attention to the focal objects than to the contexts, $F\text{s} > .5$, $p < .01$.

Discussion

The objective of this study was to explore the effects of stimulus category on attentional orienting and engagement by analyzing eye movements. There were three major findings. First, nonhuman animals were attended to more often and were attended to for longer periods of time than inanimate objects. The same pattern held for the human contexts (vs. the nonhuman contexts). Second, the effects of category, valence, and context interacted; specifically, negative animals and objects with human contexts attracted comparable attention, as indexed by the number of fixations and gaze duration. Third, the attentional bias to negative pictures appeared during the first fixation for the focal objects and lasted for the whole presentation of the picture's contexts. These results highlighted attentional bias to animate parts of a picture and clarified that the effects of category, valence, and picture context interacted to influence attentional allocation at different stages.

Attentional Bias to Animate Features of Pictures

One novel finding of our study is the importance of animate features in attentional processing. We found that nonhuman animals attracted more attention than inanimate objects in both the orienting and the engagement periods. In addition, although participants paid less attention to picture contexts than to focal objects, human contexts attracted more attention than nonhuman contexts when participants attended to the context. The attentional bias to animal pictures has been observed in previous behavioral studies (e.g., Öhman, Flykt, & Esteves, 2001, Öhman, Lundqvist, & Esteves, 2001b; Lipp et al., 2004; New et al., 2007). Changes in animal pictures were more quickly detected than changes in object pictures (New et al., 2007). But in previous studies, attentional bias to emotional stimuli was usually mixed with category effect, and the effect of context was addressed less. For example, emotional stimuli usually contained human or human parts, whereas neutral stimuli contained inanimate object information (e.g., Nummenmaa et al., 2006). Our study suggests a mechanism of enhanced detection to animate parts of pictures: animate features of stimuli, whether in focal objects or in contexts, attracted more attention.

Moreover, our study clarified that category interacts with emotion and context to influence attentional allocation in different stages. The interaction between category and valence appeared at the first fixation duration, and that between category and context appeared at the first fixation probability. At the first fixation, the animal pictures in negative valence, but not in neutral, were attended to for a longer period of time than inanimate objects. Previous studies have provided inconsistent findings on whether attentional bias to animals is limited to negative stimuli (for review, see Öhman, 2007). By separating the attentional orienting and engagement periods, our results indicate that negative valence is more important for the orienting bias to animals during the early stage of the scene processing. The negative animals can be agents to initiate goal-directed behavior (Rakison & Poulin-Dubois, 2001). Therefore, attending to these stimuli, especially in the early stage, may help people evaluate threatening situations more quickly and accurately (Heberlein & Adolphs, 2004; Schultz, Friston, O'Doherty, Wolpert, & Frith, 2005; New et al., 2007). The category effect was also attenuated for focal objects with human contexts (vs. nonhuman contexts) for the fixation probability, suggesting that human information in the contexts attract more attention even at the first fixation.

At the later stage, category interacted with emotional valence and context. The focal objects with human contexts were fixated on less frequently and for shorter duration than those without human contexts; this was associated with the fact that participants allocated more attention to the human contexts. What is more important is that the category effect disappeared in negative pictures with human contexts; there were a comparable number of fixations and fixation durations on negative animals versus objects. Emotional stimuli with human contexts may attract more attentional resources because human contexts imply that people can initiate potential actions to inanimate objects, possibly resulting in threatening danger that is comparable to nonhuman animals. From a neural mechanistic point of view, the amygdala is important in processing emotional, human-related (for reviews, see Adolphs, 2009, 2010; Phelps, 2006) and animal information (Yang et al., 2011). The activation of the amygdala by these types of information could lead to stronger activation in these regions by feedback projections (Amaral, 2003; Phelps & LeDoux, 2005; Whalen, 1998), which in turn could lead to increased attention to animate parts of the pictures.

Effects of Category and Other Factors in Eye Movements

Previous studies have suggested that semantic knowledge is a determinant of when and where fixations are located (Castelhano & Henderson, 2008; Henderson, 2003; Rayner, 1998, 2009). Eye-tracking studies have found that the essence of a picture is abstracted very quickly (for reviews, see Chua et al., 2005; Henderson, 2003; Rayner, 1998), even before the eyes begin to move (Calvo et al., 2008; Rayner, 2009). In previous studies, when participants were presented with a scene for 40 ms, they could extract enough information (Castelhano & Henderson, 2008), and the semantic analysis and categorization of objects seemed to occur within 150–160 ms of scene onset (Gordon, 2004). In addition, when meaningful information is presented, integration of information occurs at a higher abstract level of representation rather than at a lower visual level. Consistent with this view, in our study, the attentional bias to animate parts appeared during the first fixation in the form of longer duration. This suggests that the animate bias is based on the difference in semantic or conceptual representation between nonhuman animals and inanimate objects.

On the other hand, studies have suggested that factors such as affective features, picture size, visual features, familiarity, and complexity influence eye movements (Henderson, 2003; Rayner, 1998). Our results provide evidence that attentional bias to animate parts of pictures occurred after the confounding factors were optimally controlled and analyzed. First, animal and object pictures were matched in their emotional valence and arousal. This tactic enabled us to exclude the possibility of differences between nonhuman animals and inanimate objects due to valence or arousal mismatches. Second, familiarity and complexity ratings were controlled across categories. Although there were still some rating differences between categories, the discrepancies between the eye-tracking data and the rating data suggest that the differences cannot account for eye-movement patterns. For example, in the familiarity rating, there was significant interaction between valence and category, but animals in both negative and neutral valence attracted more attention than inanimate objects in attentional engagement. In the complexity rating, although the contexts of nonhuman animals were rated as more complex than those of objects, they attracted less attention. Moreover, our results show that including familiarity or complexity as a covariate did not influence significant category effects on the eye-movement parameters, and adding factor of category after familiarity or complexity into the multiple regression significantly increased the R values for eye-movement parameters. Collectively, these data indicate that picture familiarity and complexity are not the determinants of eye-movement parameters.

Third, most visual features were optimally controlled for across categories, ruling out the possibility that the category difference is explained by visual features. Visual features influence when and where to move the eyes and how long the fixation lasts (Henderson, 2003; Rayner, 2009), especially in early attentional selection (Henderson, 2003; Henderson & Hollingworth, 1999; Honey, Kirchner, & VanRullen, 2008; Rayner, 2009). The only significant category-related effects were in picture power and visual saliency. However, the power value of focal animal pictures did not differ significantly from that of inanimate objects under different conditions. The category effect for the visual saliency appeared in pictures with human contexts; but category effect in eye movements was manifested whether or not there was a human context. In addition, including power and saliency as covariates did not influence any of the eye-movement parameters, and adding them into the multiple regression analysis did not significantly increase the R values for any eye-movement parameters. These results suggest that visual features do not influence eye movements for different picture categories.

In summary, the results support the view that semantic differences between animate (both nonhuman animals and human contexts) and inanimate objects account for the majority of the bias in eye-movement patterns. In practice, the extent to which perceptual features determine eye movements is a matter of debate (Henderson, 2003). The correlations between low-level features and eye movements decrease after the stimulus onset and when a visual pattern becomes more meaningful (Parkhurst et al., 2002; Henderson, 2003). Some models begin to combine top-down information with a perceptual-based saliency map to better account for eye movements (e.g., Torralba et al., 2006; Wolfe, 1994; for review, see Itti & Koch, 2001).

Attentional Bias to Negative Pictures

We found that emotion interacted with category and context at different stages. During the first fixation, participants fixated longer on negative (vs. neutral) focal objects when pictures were nonhuman animals. This observation is consistent with previous studies that have shown emotional pictures attracted more attention during early stages of processing. For example, when subjects were presented with two pictures simultaneously, the probability of the first fixation and the proportion of viewing time during the first 500 ms were higher for both negative and positive pictures (Calvo & Lang, 2004). However, we did not find a significant main effect of emotion for focal object AOIs in the number of gaze fixations and gaze duration. The reason for it may be due to participants' avoidance of threat (Gerdes, Alpers, & Pauli, 2008; Mogg & Bradley, 1999) or more efficient processing of emotional pictures (Calvo et al., 2007). It may also be related to task requirement. Because participants had to respond to a question after viewing a picture, they had to view the entire scene. This could explain why the emotional advantage in eye movement disappeared in later stages of processing. Similarly, when participants were asked to fixate on either emotional or neutral pictures, they were automatically biased to emotional pictures during the first fixation, but they were able to deliberately adjust their eye movements during the later stages of processing (Nummenmaa et al., 2006).

The results of emotional effects described here have two implications. First, consistent with previous findings, our study indicates that at the first fixation, negative pictures are attended to more than neutral pictures. In the visual search task, fear-relevant search is unaffected by the location of the focal object in the display or by the number of distracters (Öhman, Flykt, & Esteves, 2001a). Second, by separating the effects of focal objects and contexts, our results indicate that the negative bias exists in viewing contexts. Most previous studies that found a significant emotion effect used animate pictures, such as pictures with social contexts (e.g., Calvo & Lang, 2004; Nummenmaa et al., 2006). Our results show that participants fixated on the contexts of negative pictures for longer durations during the whole presentation. This suggests that more attentional allocation to negative pictures may be partly due to attentional bias to their contexts.

Further studies are needed to address the following issues. First, although there is evidence that category information can be extracted in a very short time (Gordon, 2004), whether animate bias occurs for unconscious processing needs further investigation. Second, whether the animate bias is related to cultural variation is unclear. Studies have shown that Chinese participants attend more to the background of a picture, whereas Americans fixate more to focal objects (Chua et al., 2005; but see Rayner, 2009). It would be interesting to explore whether animate bias is specific to Chinese culture.

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Appendix

Picture Information

Concepts	Negative				Neutral			
	Human context		Nonhuman context		Human context		Nonhuman context	
Animal	Bear	1	Bear	2	Cattle	8	Cattle	5
	Crocodile	4	Crocodile	6	Dragonfly	6	Dragonfly	8
	Rat	4	Rat	7	Frog	1	Frog	2
	Roach	6	Roach	4	Hedge pig	1	Hedge pig	3
	Scorpion	3	Scorpion	4	Ladybug	4	Ladybug	5
	Shark	3	Shark	2	Pig	4	Pig	6
	Snake	6	Snake	2	Turtle	6	Turtle	1
	Spider	3	Spider	3				
Object	Negative				Neutral			
	Axe	4	Axe	2	Broom	1	Broom	2
	Broadsword	1	Broadsword	3	Grass cutter	7	Grass cutter	9
	Chainsaw	3	Chainsaw	4	Hammer	5	Hammer	2
	Gun	8	Gun	6	Mouse touch	2	Mouse touch	4
	Machine gun	3	Cannon	1	Scissors	5	Scissors	5
	Gunsnipe	2	Snipe gun	4	Tractor	6	Tractor	3
	Knife	2	Knife	2	Washbasin	1	Washbasin	2
	Syringe	7	Syringe	8	Wrench	3	Wrench	3

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