Effects of decision level on rapid natural scene categorization

Sachio Otsuka [(1)]（otsuka.sachio.65w@st.kyoto-u.ac.jp）
Jun Kawaguchi [(2)]
〔[(1)] Japan Society for the Promotion of Science, [(2)] Nagoya University〕

自然情景の高速カテゴリー化における判断レベルの影響

大塚 幸生 [(1)]、川口 潤 [(2)]
[(1)] 日本学術振興会
[(2)] 名古屋大学 大学院環境学研究科

要約

本研究では、自然情景の高速認知における判断レベルの優位性を検討した。実験参加者は、30 ms あるいは 70 ms 間画面に呈示される自然情景からターゲットを検出して、基本レベル（鳥と判断）あるいは上位レベル（動物と判断）でカテゴリー化することが要求された。ターゲットと非ターゲット（乗り物）が異なるカテゴリーに属するように設定された実験 1 では、30 ms の呈示時間条件において上位レベルよりも基本レベルでカテゴリー化する方が課題成績が高くなった。しかしながら、基本レベルの判断条件における非ターゲットがターゲットと同じ上位レベルの概念を共有するように設定された実験 2 では、特に 30ms の呈示時間条件で基本レベルよりも上位レベルでカテゴリー化する方が成績が高くなった。これらの結果に基づいて、自然情景の認知における基本レベルの判断は常に優位ではなく、判断レベルの優位性は当該のカテゴリー化処理が非ターゲットのカテゴリーによって制約を受けるか否かに依存することが示唆された。

Key words

natural scene perception, basic-level categorization, superordinate-level categorization, reaction times, rapid serial visual presentation

1. Introduction

In general, it is well known that there are three levels of categorization (e.g., Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976). For example, on seeing a “canary,” we essentially categorize it as a bird, which refers to the basic-level category, not as an animal or a canary. Animal refers to the superordinate level and canary refers to the subordinate level. As for object recognition, visual processing requires a basic-level identification before undertaking superordinate-level categorization, and it has been shown that a superordinate-level name is used to name groups of objects from the same basic-level categories (e.g., Jolicoeur, Gluck, & Kosslyn, 1984; Rosch et al., 1976). Currently, the basic-level advantage has been explained by the entry-level theory (Jolicoeur et al. 1984), the differentiation theory (e.g., Murphy & Brownell 1985), and the parallel distributed processing (PDP) theory (e.g., Rogers & Patterson, 2007).

Concerning the effect of decision level in natural scene recognition, Grill-Spector and Kanwisher (2005) suggested that people categorized objects in natural scenes at the basic level immediately after viewing them. Grill-Spector and Kanwisher required participants to perform three tasks with various exposure durations: detection of objects in natural images, in which participants responded if scenes containing objects were presented from nonobject textures; basic-level categorization, such as a dog and a car; and subordinate-level identification, such as a German shepherd and a Volkswagen Beetle. The performance of basic-level categorization was the same as that of object detection, irrespective of the exposure duration. Furthermore, subordinate-level categorization showed the worst performance among the three tasks.

The research on natural scene categorization has provided an intriguing suggestion about the above topic. VanRullen and Thorpe (2001) asked participants to categorize a target object, which was briefly presented in a natural scene for 20 milliseconds (ms), as an animal or a vehicle. Median reaction time (RT) was about 350 ms and the percentage of correct responses was about 95 %. Therefore, VanRullen and Thorpe argued that such rapid processing (i.e., superordinate-level categorization) was not specific to the basic-level categorization and that any visual-processing task requiring a high-level analysis of the visual scene seems unlikely to be performed with much shorter RTs than those of superordinate categorization. However, they did not directly compare basic-level categorization and superordinate-level categorization.

One of alternative interpretations of VanRullen and Thorpe’s (2001) results could be as follows. Since there was no backward masking, participants could perform the categorization task based on the sufficient amount of information available for processing. As a result, it is possible that they were able to categorize targets as animal or vehicle very rapidly and accurately, as in basic-level categorization. Bacon-Macé, Macé, Fabre-Thorpe,

and Thorpe (2005) reported a similar performance of superordinate-level categorization, with stimulus onset asynchronies (SOAs) of 81 and 106 ms between natural images and backward mask stimuli respectively. Given that exposure duration (or SOA) and backward masking are important for the performance of natural scene recognition, it is possible that people may still be able to categorize target objects more rapidly and accurately in natural scenes at the basic level than at the superordinate level, when the exposure duration of images is short, with backward masking (i.e., people cannot use a sufficient amount of the information available for processing). Indeed Grill-Spector and Kanwisher (2005) showed that the performance of basic-level categorization increased as a function of exposure duration with backward masking (see also Bacon-Macé et al., 2005; Mack, Gauthier, Sadr, & Palmeri, 2008; Mack & Palmeri, 2011). Considering these findings, we can predict that basic-level categorization may still be superior to superordinate-level categorization when exposure duration is short with backward masking. In other words, the logic is as follows: The threshold of basic-level categorization is lower than that of superordinate-level categorization. (A similar idea was proposed by Rogers & Patterson, 2007, but it has not been tested with natural images.) When the amount of information available for processing is well over the thresholds of both basic-level and superordinate-level categorizations (e.g., long duration of images with backward masking), people can categorize targets in natural scenes very rapidly and accurately at the superordinate level, just as they can at the basic level. However, when the amount of information available for processing is only slightly over the threshold of basic-level categorization (e.g., short duration of images with backward masking), people can categorize targets in natural scenes more rapidly and accurately at the basic level than at the superordinate level.

In addition, another interpretation is that rapid superordinate-level categorization reported by the previous studies may be based on the processing of detection, but not superordinate-level decision. In recent studies of object recognition, Large, Kiss, and McMullen (2004) and Large and McMullen (2006) set up the constrained basic-level and superordinate-level conditions in categorization task. In this condition, participants detect and categorize target objects at the basic level (e.g., dogs) with nontargets containing animals excluding targets, and at the superordinate-level (e.g., animals) with nontargets containing vehicles. They found that, overall, superordinate-level categorization was faster than basic-level categorization, suggesting that the basic-level decision was not always superior to the superordinate-level decision. More recently, Bowers and Jones (2008) used the easy-categorization task in which, for example, participants categorized target objects as dogs with nontarget images containing buses, and the difficult-categorization task in which, for example, they categorized them as dogs with nontarget images containing cats. They found that the performance of easy categorization was better than that of difficult categorization. These studies may indicate that the superiority of decision level is influenced by the experimental context, in which nontargets shared the superordinate-level concept with targets. Indeed, VanRullen and Thorpe (2001) used a very wide range of distractor images, which were outdoor or indoor scenes, natural landscapes or street scenes with buildings and roads, pictures of food, fruits, vegetables, or plants, houses, man-made objects or tools. In fact, Macé, Joubert, Nespoulous, and Fabre-Thorpe (2009) have reported that the constrained basic-level categorization is more difficult than the superordinate-level categorization and unconstrained basic-level categorization. However, because their duration of natural scenes was 26 ms without backward masking, the time-course of constrained basic-level categorization is still unclear.

Therefore, in this article, we examine the visual categorization of natural scenes using a rapid serial visual presentation (RSVP) with backward masking and constrained condition (Large et al., 2004; Large & McMullen, 2006). Based on previous studies (Bacon-Macé et al., 2005; Grill-Spector & Kanwisher, 2005; Mack et al., 2008), it is possible to say that the 30–40 ms duration of images is critical in enabling people to categorize a target in a natural scene. Thus, in this study we prepared two exposure durations (30 and 70 ms). In Experiment 1, we examined the effect of decision level for natural scenes in which participants were asked to categorize a target object in a natural scene as a bird category or an animal category, under the unconstrained categorization condition. In Experiment 2, we examined the effect of decision level in the constrained categorization condition.

2. Experiment 1

2.1 Method

2.1.1 Participants

Twelve undergraduate students (7 men and 5 women, age range = 19 to 21 years) participated in Experiment 1 for course credit. All were right-handed and reported normal or corrected-to-normal visual acuity. All participants signed informed consent forms.

2.1.2 Apparatus and Stimuli

This experiment was controlled by an AV tachistoscope (IWATSU ISEC, IS-703). Visual stimuli were presented on a color monitor (MITSUBISHI, RDF221H). The refresh rate of the monitor was 100 Hz. Image resolution was 512 × 512 pixels. Participants were seated in a room, at about 80 cm from the computer screen. Participants' responses were measured using the response unit of the AV tachistoscope.

Seven hundred and twenty color pictures were selected from commercially available CD-ROMs. We selected 240 images including birds; 120 images including animals excluding birds, for example, a dog, cat, ape, and lion, and 360 nontarget images

including flowers, vehicles, landscapes of city and seaside, natural landscapes, and sky scenes. In the basic-level categorization condition, 120 target images including birds and 120 nontarget images were presented. In the superordinate-level categorization condition, half the target images contained birds (120 images) and the other half included animals excluding birds (120 images). The remaining images were nontarget images (240 images). We made four experimental lists of bird images, two lists of animal images, and twelve lists of nontarget images. These pictures subtended a visual angle of about 10 degrees vertically and 10 degrees horizontally. No picture was ever presented repeatedly.

2.1.3 Design

The manipulated variables were the decision level (basic and superordinate levels) and duration (30 and 70 ms). These were within-subjects factors. In the basic-level condition, participants were required to categorize a target object as a bird. In the superordinate-level condition, they were required to categorize a target object as an animal.

2.1.4 Procedure

This experiment consisted of 240 basic-level trials and 480 superordinate-level trials. The experimental trials were divided into 6 blocks, and each block comprised 120 trials, for a total of 720 trials. The presentation order of images was random, and two durations were randomly presented within blocks to the same extent. The order of decision level was counterbalanced across participants. Half the pictures included targets and the other half contained nontarget images in one block. Before the experimental trials of each decision level, participants performed 48 practice trials following the delivery of instructions.

Figure 1 shows a trial schedule. A fixation cross was presented in the center of the computer screen for 300 ms. After a blank screen was presented for 200 ms, a natural image was presented for 30 or 70 ms, according to each duration. Following natural scene presentation, a mask of white noise appeared for 100 ms. Participants were instructed to decide whether the images contained birds in the basic-level condition or animals in the superordinate-level condition, and in such case, they pressed

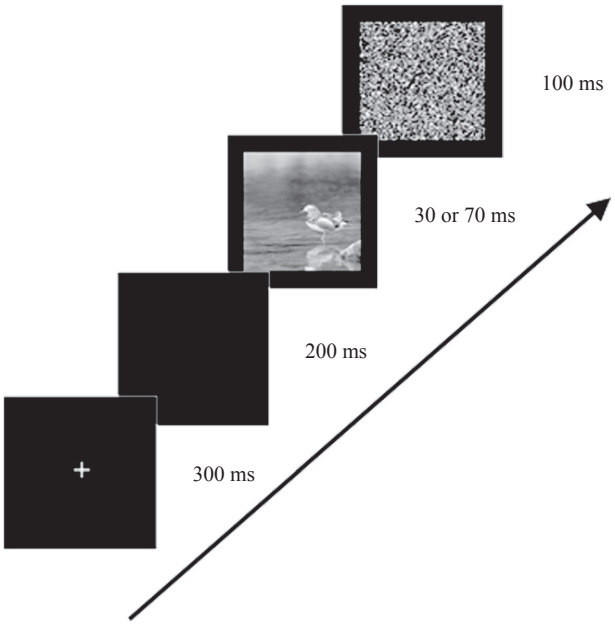

Figure 1: Trial schedule in the experiment. The time schedule of trials was identical both for the basic- and superordinate-level categorization tasks

the response key as quickly and accurately as possible with the index finger of their dominant hand. Otherwise, they did not press any key (i.e., a go/no-go task).

2.2 Results and Discussion

Mean RTs and percentage corrects were calculated for each experimental condition. We excluded trials with errors and other trials in which RTs deviated 2 *SD* from the RT analyses. This trimming procedure was independently performed for each participant and each condition. This resulted in the exclusion of 4.2 % of the responses. Similar to Grill-Spector and Kanwisher (2005), accuracy scores were corrected for guessing (Green & Swets, 1966): accuracy (corrected for guessing) = 100 * (hits – false alarms)/(1 – false alarms).

Table 1 shows mean RTs and percentage corrects for each condition. A two-way ANOVA was run on the decision level

Table 1: Mean reaction times (RTs, in milliseconds), standard errors, and percentage of corrects (%C) as a function of each condition in Experiment 1

		Duration							
		30 ms				70 ms			
Level	Category	RT	SE	%C	SE	RT	SE	%C	SE
Basic	Bird	341	10	94.1	1.8	339	10	98.6	0.4
Superordinate	Bird	365	15	92.0	1.7	343	14	97.9	0.5
	Animal	367	19	81.4	3.5	343	12	93.5	1.4

Note: Accuracy scores were corrected for guessing (Green & Swets, 1966): accuracy (corrected for guessing) = 100 * (hits – false alarms)/(1 – false alarms)

(basic and superordinate levels) and duration (30 and 70 ms). The RT data showed that the effect of decision level was not significant, F (1, 11) = 2.44, MSE = 917.30, p = .147, but the effect of duration was significant, F (1, 11) = 7.49, MSE = 224.06, p = .019. Participants responded to target images faster at a duration of 70 ms (341 ms) than at 30 ms (353 ms). In addition, a two-way interaction was reliable, F (1, 11) = 7.72, MSE = 144.30, p = .018, and indicated that the effect of decision level was significant at a duration of 30 ms, F (1, 11) = 4.86, MSE = 669.57, p = .050, but not at that of 70 ms, $F < 1$. The analysis for percentage corrects data showed a significant main effect of duration , F (1, 11) = 16.08, MSE = 20.01, p = .002, but the effect of decision level and the interaction between decision level and duration were not significant, F (1, 11) = 3.00, MSE = 8.22, p = .111, F (1, 11) = 1.11, MSE = 5.70, p = .315, respectively. Participants responded to target images more accurately at a duration of 70 ms (98.2 %) than at that of 30 ms (93.0 %).

In summary, the results of RTs showed that when the duration of natural images was 30 ms, participants responded to targets in the basic-level condition more rapidly than to those in the superordinate-level condition. In contrast, at a duration of 70 ms, they responded to targets at the same level of speed. These findings suggest the superiority of basic level in the earlier stage of visual processing (i.e., at a duration of 30 ms). However this superiority disappears in the later stage (i.e., at a duration of 70 ms), and people are able to categorize targets rapidly at the superordinate level.

3. Experiment 2

In Experiment 2, we examined whether the superiority of superordinate-level decision in rapid natural scene categorization was found under the constrained condition (e.g., Large et al., 2004; Large & McMullen, 2006). In the basic-level condition, participants were required to categorize a target object as a bird with nontargets containing animals excluding birds, and in the superordinate-level categorization, they were required to categorize a target object as an animal with nontargets containing vehicles. If the basic-level superiority is less subject to the experimental context in which nontargets shared the superordinate-level concept with targets, we should still find better performance in the basic-level condition than in the superordinate-level condition. However, if the basic-level superiority in natural scene categorization is influenced by the above context, we will observe better performance in the superordinate-level condition than in the basic-level condition.

3.1 Method

3.1.1 Participants

Twelve undergraduate students (4 men and 8 women, age range = 18-21 years) took part in Experiment 2 for course credit. All were right-handed and reported normal or corrected-to-normal visual acuity. All participants signed informed consent forms.

3.1.2 Stimuli

The natural images containing birds and animals excluding birds were identical to those used in Experiment 1 (240 images each for birds and 240 images for animals). In addition to these images, we selected 240 nontarget images containing vehicles, which were electric trains, airplanes, ships, cars, and so on. A total of 720 pictures were used in Experiment 2. In the basic-level categorization, half were target images including birds, and the other half were nontarget images including animals excluding birds. In the superordinate-level categorization, half the target images contained birds and the remaining half included animals excluding birds. The others in this condition were nontarget images including vehicles. We made four experimental lists for bird images, two lists for animal images, and two lists for vehicle images.

3.1.3 Design

The manipulated variables were the decision level (basic and superordinate levels) and duration (30 and 70 ms). These were within-subjects factors.

3.1.4 Procedure

As in Experiment 1, this experiment consisted of 240 basic-level trials and 480 superordinate-level trials. The experimental trials were divided into 6 blocks, with each block comprising 120 trials, for a total of 720 trials. The presentation order of images was random, and two durations were randomly presented within blocks to the same extent. In one block, the pictures included target objects and the remaining half were nontarget images. The order of decision level was counterbalanced across participants. Before the experimental trials of each decision level, participants performed 48 practice trials following the delivery of instructions. In the basic-level condition, participants were required to categorize a target object as a bird with nontargets containing animals excluding birds. In the superordinate-level condition, they were required to categorize a target object as an animal with nontargets containing vehicles.

3.2 Results and discussion

The trimming procedure was conducted as in Experiment 1, and resulted in the exclusion of 4.5 % of the responses.

Table 2 shows mean RTs and percentage corrects for each condition. A two-way ANOVA was run on the decision level (basic and superordinate levels) and duration (30 and 70 ms). The RT data showed that the effects of decision level and duration of natural images were significant, F (1, 11) = 37.50, MSE = 354.02, $p < .001$, F (1, 11) = 20.06, MSE = 221.54, p = .001, respectively. Participants responded to target images faster in the superordinate-level categorization (362 ms) than in the basic-level categorization (396 ms), and they responded to target images faster at a duration of 70 ms (369 ms) than at a duration of 30 ms (389 ms). In addition, the interaction between decision

Table 2: Mean reaction times (RTs, in milliseconds), standard errors, and percentage of corrects (%C) as a function of each condition in Experiment 2

		Duration							
		30 ms				70 ms			
Level	Category	RT	SE	%C	SE	RT	SE	%C	SE
Basic	Bird	409	17	84.2	3.1	383	13	95.3	1.6
Superordinate	Bird	369	14	94.6	2.1	356	12	98.1	1
	Animal	381	16	91.1	2.6	360	14	96.4	1.5

Note: Accuracy scores were corrected for guessing (Green & Swets, 1966): accuracy (corrected for guessing) = 100 * (hits – false alarms)/(1 – false alarms)

level and duration of natural images was reliable, F (1, 11) = 6.15, MSE = 92.04, p = .031, which indicated that the effect of decision level was significant at durations of both 30 and 70 ms, F (1, 11) = 28.29, MSE = 341.56, p < .001, F (1, 11) = 39.99, MSE = 104.50, p < .001, respectively. The difference of RTs between basic-level and superordinate-level categorization was much greater at the duration of 30 ms (40 ms) than at the duration of 70 ms (26 ms), t (11) = 2.48, p = .031.

The analysis for percentage corrects data showed that the main effects of decision level and duration of natural images were significant, F (1, 11) = 14.64, MSE = 35.86, p = .003, F (1, 11) = 20.61, MSE = 30.79, p = .001, respectively, indicating that participants responded to target images more accurately in the superordinate-level categorization (96.4 %) than in the basic-level categorization (89.7 %), and they responded to target images at a duration of 70 ms (96.7 %) more accurately than at a duration of 30 ms (89.4 %). In addition, the interaction between decision level and duration of natural images was significant, F (1, 11) = 20.00, MSE = 8.72, p = .001, indicating that the effect of decision level was significant at a duration of 30 ms, F (1, 11) = 20.70, MSE = 31.51, p = .001, but not at a duration of 70 ms, F (1, 11) = 3.60, MSE = 13.08, p = .084.

In summary, the results of RTs and percentage corrects showed that when the duration of natural images was 30 ms, unlike Experiment 1, participants responded to targets in the superordinate-level condition more rapidly and accurately than to those in the basic-level condition. In contrast, at a duration of 70 ms, although RTs for birds in the superordinate-level categorization were still faster than those in the basic-level categorization, the accuracies did not differ between the basic-level and superordinate-level categorizations. These results suggest that rapid natural scene categorization is influenced by the context of distractors in the task. In the earlier stage of visual processing (e.g., at a duration of 30 ms), the concept of basic level (e.g., a bird) may be activated, but this activation would not be sufficient, and so it would be inhibited by the superordinate-level concept (e.g., an animal) that the targets and distractors shared. In the superordinate-level condition, the concept of superordinate level (e.g., an animal) is activated, and this concept would not be inhibited by the concept of distractors because they did not share the concept of superordinate level (e.g., an animal and a vehicle). In the later stage of visual processing (e.g., at a duration of 70 ms), the concept of basic level was activated well compared to that in the earlier stage, so the activation of basic-level concept would not be affected by the superordinate-level concept that the targets and distractors shared. These findings suggest that in natural scene recognition, basic-level categorization is not always found to be superior, and the superiority of decision level depends on whether categorization is constrained or unconstrained. We should note that the superiority of superordinate-level categorization is reduced or disappears as a function of the duration of natural images.

4. General discussion

In this article, we examined the superiority of decision level in rapid natural scene categorization with backward masking and constrained categorization condition, by manipulating the exposure duration. In Experiment 1 which adopted the unconstrained categorization as well as the previous studies (e.g., Thorpe, Fize, & Marlot, 1996; VanRullen & Thorpe, 2001), although people could categorize target objects at the superordinate level as well as at the basic level when they were able to utilize abundantly the amount of information available for processing natural scenes (i.e., at a duration of 70 ms), we showed that the basic-level categorization was still superior to the superordinate-level categorization when they were able to use a lesser amount of information (i.e., at a duration of 30 ms). The former (no advantage of the basic-level decision at a duration of 70 ms) is consistent with the assertion from previous studies of natural scene recognition that people can very rapidly and accurately categorize target objects in natural images at the superordinate level (VanRullen & Thorpe, 2001). In fact, Thorpe and his colleagues (Thorpe et al., 1996; VanRullen & Thorpe, 2001) presented natural images for 20 ms without backward masking, and the RTs were short and the accuracies were as high as they are in our data. Although the latter (basic-level advantage at a duration of 30 ms) is apparently matched with the idea of ordinary categorization research (e.g., Jolicoeur et al., 1984; Rosch et al., 1976),

it is noteworthy in this article that the superiority of basic-level categorization is found in rapid natural scene recognition, which thus provides a warning against VanRullen and Thorpe's (2001) proposal. It is possible that, at the duration of 70 ms, participants would process natural images well enough, before the presentation of mask stimuli, on a par with no backward masking. Our results support the suggestion that the amount of information available for processing natural images influences the performance of object categorization in natural scenes (i.e., the accumulation of perceptual information over time, Bacon-Macé et al., 2005). In addition, our findings imply that in the unconstrained natural scene categorization, people need a lower amount of information at the basic level than at the superordinate level.

However, note that we observed the superordinate-level advantage in the constrained categorization condition, consistent with the results of Macé et al. (2009). In light of the results of Experiments 1 and 2, we propose the flexibility of superiority of decision level in rapid natural scene categorization. That is, the threshold of categorization level may change on the basis of semantic relation between target and distractor. In the constrained categorization condition, the threshold of basic-level decision may be higher than that of superordinate-level decision because it is difficult for us to distinguish between birds and other animals which share the same superordinate-level concept (i.e., animal). Our results may also be approximately consistent with the recent model of object recognition (Rogers & Patterson, 2007), considering the ease/difficulty as a function of the relation between target and distractor. Their PDP theory supposes that the model's internal state will begin to pass through the "animal" region first, which means that the name animal ought to begin to activate before the name bird. The basic-level effects are due to the effects of similarity-based generalization. Superordinate names begin to activate first because they apply broadly across a wide range of semantically related items, and basic names apply across a narrower region of the space because their activation starts later but accelerates more rapidly. According to this PDP theory, one interpretation is that at a duration of natural images of 30 ms, both the basic-level and superordinate-level names were activated, but the activation of the basic-level name may have accelerated more rapidly than that of the superordinate-level name because basic-level decision is easy in the unconstrained condition, and so participants responded more rapidly to the target objects in the basic-level categorization task. At a duration of 70 ms, because the slower activation of the superordinate-level name exceeded a threshold and provided a confident response (Rogers & Patterson, 2007), both the basic-level and superordinate-level decisions may show a similar pattern. On the other hand, in Experiment 2, the superordinate-level names were activated faster than the basic-level names so that basic-level decision is difficult under the constrained condition. Consistent with the explanation by the PDP theory, it would appear that this advantage then decayed or was eliminated. Although it would appear that our results are consistent in part with the PDP theory, note that the same duration of natural images of 30 ms with backward masking produced both the basic-level and the superordinate-level advantages, which is the additional new finding over Macé et al. (2009).

The basic-level and superordinate-level advantages observed in the current study support the suggestion of previous studies (Bowers & Jones, 2008; Mack et al., 2008). These studies provided proof against the proposal by Grill-Spector and Kanwisher (2005), with manipulation of stimulus and task, and Mack et al. (2008) proposed that object detection and basic-level categorization were different types of perceptual decisions that could be made easier or harder, or slower or faster, depending on a variety of task factors. In our study, basic-level categorization in Experiment 1 may be an easy-categorization task, because the nontargets did not belong to the same category as the targets. On the other hand, the basic-level categorization in Experiment 2 may be a difficult-categorization task so that nontargets belonged to the same superordinate-level category as targets, different from superordinate-level categorization. Some might point out the possibility that the basic-level advantages observed in Experiment 1 did not reflect the basic-level categorization, but the object detection suggested by Bowers and Jones (2008), because the nontargets in these experiments were not from the same superordinate category as the target. However, unlike previous studies (Bowers & Jones, 2008; Grill-Spector & Kanwisher, 2005), in our basic-level categorization, we did not use the nonobject textures as nontargets, and in most cases, the nontarget images contained objects (e.g., flowers, trees, vehicles, and buildings), which implies that the participants could not perform the task based on the decision whether an object was presented.

In conclusion, we present new findings on rapid natural scene categorization. The results showed that people can rapidly categorize target objects in natural images at the superordinate level as well as at the basic level (e.g., at a duration of 70 ms). In addition, under the unconstrained categorization situation, people still categorize objects more rapidly at the basic level than at the superordinate level (e.g., at a duration of 30 ms). However, this is limited to the unconstrained basic-level decision, and the superordinate-level categorization is advanced in the constrained basic-level categorization.

References

Bacon-Macé, N., Macé, M. J.-M., Fabre-Thorpe, M., & Thorpe, S. J. (2005). The time course of visual processing: Backward masking and natural scene categorisation. *Vision Research*, 45, 1459-1469.

Bowers, J. S., & Jones, K. W. (2008). Detecting objects is easier than categorizing them. *Quarterly Journal of Experimental Psychology*, 61, 552-557.

Green, D. M., & Swets, J. A. (1966). *Signal detection theory and psychophysics*. New York: John Wiley & Sons.

Grill-Spector, K., & Kanwisher, N. (2005). Visual recognition: As soon as you know it is there, you know what it is. *Psychological Science*, 16, 152-160.

Jolicoeur, P., Gluck, M. A., & Kosslyn, S. M. (1984). Pictures and names: Making the connection. *Cognitive Psychology*, 16, 243-275.

Large, M.-E., Kiss, I., & McMullen, P. A. (2004). Electrophysiological correlates of object categorization: Back to basics. *Cognitive Brain Research*, 20, 415-426.

Large, M.-E., & McMullen, P. A. (2006). Hierarchical attention in discriminating objects at different levels of specificity. *Perception & Psychophysics*, 68, 845-860.

Macé, M. J.-M., Joubert, O. R., Nespoulous, J.-L., & Fabre-Thorpe, M. (2009). Time-course of visual categorizations: You spot the animal faster than the bird. *PLoS ONE 4*, e5927.

Mack, M. L., Gauthier, I., Sadr, J., & Palmeri, T. J. (2008). Object detection and basic-level categorization: Sometimes you know it is there before you know what it is. *Psychonomic Bulletin & Review*, 15, 28-35.

Mack, M. L., & Palmeri, T. J. (2011). The timing of visual object categorization. *Frontiers in Psychology*, 2, 165.

Murphy, G. L., & Brownell, H. H. (1985). Category differentiation in object recognition: Typicality constraints on the basic category advantage. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 11, 70-84.

Rogers, T. T., & Patterson, K. (2007). Object categorization: Reversals and explanations of the basic-level advantage. *Journal of Experimental Psychology: General*, 136, 451-469.

Rosch, E., Mervis, C. B., Gray, W. D., Johnson, D. M., & Boyes-Braem, P. (1976). Basic objects in natural categories. *Cognitive Psychology*, 8, 382-439.

Thorpe, S., Fize, D., & Marlot, C. (1996, June 6). Speed of processing in the human visual system. *Nature*, 381, 520-522.

VanRullen, R., & Thorpe, S. J. (2001). Is it a bird? Is it a plane? Ultra-rapid visual categorisation of natural and artifactual objects. *Perception*, 30, 655-668.

(Received September 10, 2013; accepted October 11, 2013)