The training and transfer of real-world, perceptual expertise

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Abstract

A hallmark of perceptual expertise is that experts classify objects at a more specific, subordinate level of abstraction than novices. To what extent, does subordinate level learning contribute to the transfer of perceptual expertise to novel exemplars and novel categories? In this study, participants learned to classify ten varieties of wading birds and ten varieties of owls at either the subordinate, species (e.g., "white crown heron," "screech owl") or family ("wading bird", "owl") level of abstraction. During the six days of training, the amount of visual exposure was equated such that participants received an equal number of learning trials for wading birds and owls. Pre- and post-training performance was measured in a "same/different" discrimination task in which participants judged whether pairs of bird stimuli belonged to the "same" or "different" species. Participants trained in species level discrimination demonstrated greater transfer to novel exemplars and novel species categories than participants trained in family level discrimination. These findings suggest that perceptual categorization, not perceptual exposure *per se*, is important for the development and generalization of visual expertise.

The training and transfer of real-world, perceptual expertise

An obvious difference between experts and novices is that experts have greater exposure to objects from their domain of expertise than novices. Dedicated birdwatchers go on "birding" trips where they encounter large numbers and a diverse variety of bird species. Similarly, car aficionados make it a point to attend car shows where they see the latest makes and models of automobiles. While an expert has more opportunities to "see" objects of expertise than a novice, they also recognize these objects at a different level of abstraction. Novices tend to categorize objects first at the basic level (Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976) whereas experts show a preference to identify those objects at a level that is more specific or subordinate to the basic level (Johnson & Mervis, 1997; J.W. Tanaka & Taylor, 1991). For example, a bird novice identifies an object at the basic level of "bird" in contrast to the expert birdwatcher who will identify the same bird more specifically as the subordinate level "sparrow" or "chipping sparrow". This downward shift in the level at which an object is first identified has become one of the behavioral hallmarks of perceptual expertise (Gauthier & Tarr, 1997; J.W. Tanaka & Taylor, 1991)

If object categories provide a record of the perceiver's past, they also serve as a bridge to new object instances and new object categories (Solomon, Medin, & Lynch, 1999). Based on a wealth of prior category knowledge, the owl expert, for example, should be able to identify common species of owls across a broader spectrum of viewing conditions than the novice. Similarly, the owl expert should be better able to distinguish never-before-encountered species of owls than the novice. Research indicates that experts are able to bootstrap new category learning onto to old categories (Gauthier, Williams, Tarr, & Tanaka, 1998). Participants trained in the expert recognition of artificial objects (i.e., Greebles) can learn the names of newly encountered Greebles in fewer training trials than novices (Gauthier et al., 1998). As an explanation for the expert advantage, it is plausible that the same perceptual operations that facilitated subordinate level recognition were applied to the learning of new subordinate level category representations. What is less clear is whether the transfer of perceptual expertise is broadly tuned to incorporate a wide range of object categories or narrowly focused to a more restricted class of categories.

In the current experiment, the perceptual basis of expertise and its transfer to novel object categories was investigated. Over multiple days of training, participants viewed pictures of owls and wading birds an equal number of times while categorizing one group at a general, family level (e.g., owl) and the other group at the subordinate, species level (e.g., green heron). As a pre- and post-training measure of perceptual performance, participants were administered a "same/different" discrimination task in which they judged whether two sequentially presented bird pictures were members of the "same" or "different" species. The post-test discrimination measure included the images presented in the original training condition (old instances/old species), new images of the species of owls and wading birds classified during training (new instances/old species), and new species of owls and wading birds (new instances/new species) not seen during training. If perceptual expertise is influenced by category task, participants should show better post-test discrimination of birds learned in the subordinate level learning condition than birds learned in the basic level learning condition. The discrimination should transfer to the discrimination of new images from familiar subordinate level categories and novel subordinate level categories.

Method

Participants. Twenty-eight undergraduate students from Oberlin College with normal or corrected to normal vision participated in this experiment. Participants were trained individually and received course credit for their participation.

Stimuli. The stimuli consisted of 272 digitized photographs of owls and wading birds obtained from bird identification field guides or ornithological websites on the internet (See Figure 1). The training set of 120 pictures were composed of six photographs of the ten species of owls (Barn Owl, Barred Owl, Boreal Owl, Burrowing Owl, Eastern Screech-Owl, Elf Owl, Eurasian Eagle Owl, Flammulated Owl, Great Gray Owl) and ten species of wading birds (American Bittern, Black-crowned Night-Heron, Cattle Egret, Glossy Ibis, Great Blue Heron, Great Egret, Green Heron, Least Bittern, Limpkin, Little Blue Heron). The New Instances/Old Species condition of 80 pictures included four new digitized photographs of the ten species of owls and ten species of wading birds presented during training. The New Instances/New Species condition of 74 pictures included four images of eight novel species of owls (i.e., Long-eared Owl, Northern Hawk Owl, Northern Pygmy-Owl, Northern Saw-whet Owl, Short-eared Owl, Snowy Owl, Spotted Owl, Whiskered Screech-Owl) and four images of eight novel species of wading birds (i.e., Reddish Egret, Sandhill Crane, Snowy Egret, Tricolored heron, White Ibis, Whooping Crane, Wood Stork, Yellow-crowned Night-Heron) not learned in training. The images were cropped and scaled to fit within a 300 x 300 pixel frame and placed on a white background. Images subtended a visual angle of approximately 4.8 and 6.75 degrees in the horizontal and vertical dimensions, respectively.

Procedure. The training study was conducted over a period of seven consecutive days. Half of the participants were assigned to the owl subordinate-level group and half were assigned to the wading bird subordinate-level group.

Pre-Training Assessment. On the first day of the study, participants completed a pre-assessment sequential matching task that has previously been shown to be sensitive to differences in perceptual expertise among real-world experts (Gauthier, Curran, et al., 2003). Participants were shown a bird stimulus for 150 ms on a computer monitor, followed by 300 ms mask, and a second bird stimulus for 150 ms. Participants responded "same" if the bird stimuli were members of the same species or "different" if they were from different species. For “same” trials, the birds were two different images of the same species (e.g., two different images of "screech owls"). For the “different” trials, the birds were images depicting two species from the same family (e.g., "screech owl" and "burrowing owl"). The matching task was composed of two bird families (owls, wading birds), ten training species per family, six images per species and two responses (same, different) for a total of 240 trials.

Training. After the pre-training assessment, participants were taught to categorize the ten species of owls (wading birds) at the subordinate level and ten species of wading birds (owls) at the family level. At the beginning of each block of training, participants were introduced to an owl and wading bird and its corresponding subordinate-level letter (e.g., “k” for screech owl, “j” for “burrowing owl,” etc.) or family-level letter (i.e., “w” for “wading bird,” “o” for “owl”) on the keyboard. Subordinate- and family-level category learning involved a variety of instructional methods, including naming, category verification and object classification as employed in previous studies (Gauthier & Tarr, 1997; Gauthier et al., 1998).

For the keyboard naming task, participants viewed a 250 ms fixation point, followed by a bird picture stimulus. The participant's task was to identify the stimulus at the either the subordinate-level or family-level by pressing the corresponding key (e.g., "k" for screech owl, "w" for wading bird). The picture stimulus remained on the screen for 5000 ms or until a keyboard response was made. If the participant pressed the incorrect key, they were given feedback regarding the correct response. The naming task continued until participants identified the bird stimuli with the appropriate subordinate-level and family-level responses on 100% of the trials for two consecutive blocks of training.

Following successful completion of the naming task, participants performed a category verification task in which a fixation point was presented for 250 ms, followed by a 500 ms subordinate-level word label (e.g, screech owl) or family-level (e.g., wading bird) level label that was replaced by a picture stimulus. If the picture matched the label, participants were instructed to press the key marked TRUE, otherwise they were to press the key marked FALSE. Participants received auditory feedback on correct and incorrect responses. For each block of training, there were twelve subordinate-level TRUE trials (e.g., the label "screech owl," followed by a picture of a screech owl), twelve subordinate FALSE trials (e.g., the label "screech owl," followed by a picture of a burrowing owl) , twelve family-level TRUE trials (e.g., the label "wading bird," followed by a picture of green heron) and twelve family level FALSE trials (e.g., the label "owl" followed by a picture of a green heron). On days 2 through day 6 of training, participants also performed a speeded version of the category verification task in which responses were required before a 1 sec deadline. For the normal and speeded versions, participants received auditory feedback on correct and incorrect responses.

In the object classification task, participants saw a 250 ms fixation point, followed by a 500 ms subordinate-level word label (e.g, screech owl) or family-level (e.g., wading bird) level label that was replaced by two pictures, one on the left and one on the right. The participant's task was to indicate which picture matched the word label by pressing the corresponding key marked “left” or “right”. Each species of wading bird and owl was presented once. Participants received auditory feedback on correct and incorrect responses.

On the first day of training, participants learned to name, verify and classify six owls and wading birds at either subordinate level or family level. On the second day of training, participants named, verified and classified four additional subordinate- and family-level species of owls and wading birds. On the third, fourth, fifth an sixth days of training, learning of the ten subordinate- and family-level birds was reinforced through the naming, category verification (normal and speeded) and object classification tasks.

Post-training Assessment. On the seventh day of training, participants were re-administered the sequential matching task in which two birds were judged as belonging to the same or different species following the same procedure described in the pre-training assessment. The matching task was divided into three types of tests (see Figure 1): Old Instances/Old Species, New Instances/Old Species and New Instances/New Species. The Old Instances/Old Species test was identical to the pre-assessment measure, with the exception that the number of tested images per species was changed from six to three. Thus, this test included the two bird families (owls, wading birds), ten species, three images and two types of responses for a total of 120 trials. The New Instances/Old Species test measured perceptual discrimination of the same species of owls and wading birds learned in training, but with new images. This test evaluated two families of birds (owls, wading birds) ten training species per family, three new images per species (not previously seen by the participant and two responses (same, different) for a total of 120 trials. The New Instances/New Species test investigated the discrimination of eight new species of owls (i.e., Long-eared Owl, Northern Hawk Owl, Northern Pygmy-Owl, Northern Saw-whet Owl, Short-eared Owl, Snowy Owl, Spotted Owl, Whiskered Screech-Owl) and wading birds (i.e., Reddish Egret, Sandhill Crane, Snowy Egret, Tricolored heron, White Ibis, Whooping Crane, Wood Stork, Yellow-crowned Night-Heron) not seen or learned during training. This test included two bird families (owls, wading birds), eight species per family, six images, and two responses (same, different) for a total of 192 trials. The Old Instances/Old Species test was administered first and then items from New Instances/Old Species and New Instances/New Species tests were randomly intermixed.

Results

After the first day of training, seven participants were eliminated from the study because they failed to learn the required six subordinate-level birds. Thus, a total of 21 participants remained in the study; eleven participants in the subordinate-level owl group and ten participants in the subordinate-level wading bird group. Prior to training, participants were assessed for their ability to discriminate owls and wading birds at the species level. The *d'* for owls and wading birds was 1.74 and 1.79, respectively. Hence, before training began, participants exhibited no difference in their ability to differentiate the two families of birds at the species level, $p > .05$.

Training. Reaction times were computed for correct responses only. For the category verification task, the subordinate level categorizations became increasingly faster over the course of the six days of training (as shown in Table 1). Consistent with this interpretation, the ANOVA showed reliable main effects of Category Level (family, subordinate), $F(1,15) = 69.93$, $p < .001$, and Days of Training (Day 2, Day 3, Day 4, Day 5, Day 6), $F(4,60) = 48.01$, $p < .001$ and their interaction, $F(4,60)=17.42$, $p<.001$. Although subordinate level categorizations grew increasingly faster, they were still reliably slower than basic level categorization times even at the end of six sessions of training, $p < .01$.

A similar pattern of results was found in the fast verification task, reaction times again became faster over the course of training (see Table 1, Figure 2). The ANOVA showed reliable main effects of Category Level (family, subordinate), $F(1,19) = 60.76$, $p < .001$, and Days of Training (Day 2, Day 3, Day 4, Day 5, Day 6), $F(3,57) = 16.49$, $p < .001$ and a reliable interaction between Category Level and Days of Training, $F(3,57)=5.67$, $p<.01$. However, subordinate level reaction times were still slower than basic level reaction times, $p < .01$.

Similarly, the results from the matching task demonstrated that reaction times were faster for family level than subordinate level categorizations, $F(1,19) = 101.72$, $p < .001$, and overall performance improved over the six days of training, $F(3,57) = 12.99$, *p*< .001, there was greater improvement for the subordinate level categorizations than the basic level categorizations, $F(3,57)=24.47$, $p<.001$, but were still slower than basic level categorizations, $p < .01$.

Pre- versus Post-Training Discrimination of Old Images. An initial analysis was performed to test whether post-training discrimination of the training images was better relative to pre-training discrimination (see Table 2). An analysis of variance was performed with training day (Day 1 versus Day 7) and category level (basic versus subordinate) as a within-group factor and expert type (wading bird versus owl) as a between-group factor. The ANOVA showed that the effects of training, $F\ (1,19) = 279.58$, $MSe = 41.89$, and category level, $F\ (1,19) = 172.80$, $MSe = 24.26$, were significant, $p < .001$. However, training day interacted with category level, $F\ (1,19) = 182.50$, $MSe = 16.21$, $p < .011$, such that subordinate level training reliably improved discrimination performance more than basic level training (as shown in Figure 3). Nevertheless, basic level training resulted in better discrimination than pre-training levels of discrimination, $p < .01$. The main effect of expert type or any of the other interactions were significant.

Transfer Conditions: Discrimination of New Exemplars and New Species. To test the transfer of discrimination to novel images, an ANOVA was performed with Category Level (basic, subordinate) and Transfer Images (New Exemplars, New Species) as within-group factors and Subordinate Group (wading bird, owls) as a between-group factor (see Table 3). Category Level, $F(1,19) = 25.69$, $MSe = 5.99$, $p < .001$, was significant indicating that subordinate level training produced better discrimination performance than basic level training. The factor of Transfer Images was also significant indicating that images of new exemplars were better differentiated than images of new species, $F(1,19) = 16.20$, $MSe = 1.84$, $p < .001$. The significant Category Level by Transfer Images interaction, $F(1,19) = 17.13$, $MSe = 1.06$, $p < .001$, demonstrated that subordinate level training produced a greater improvement in discrimination of new exemplar images than new species images. As indicated in Figure 3, direct comparisons showed subordinate level training produced significantly better discrimination than basic level training for images of new exemplars ($F(1, 20) = 41.78$, $p < .0001$, Greenhouser-Geisser) and images of new species($F(1,20) = 6.18$, $p < .02$, Greenhouse-Geisser). The Category Level by Transfer Images by Subordinate Group interaction, $F(1,19) = 20.55$, $MSe = 1.28$, $p < .001$, showed that subordinate level training of wading birds produced the largest improvement for discriminating new species of wading birds. Direct comparisons showed that subordinate level training enhanced discrimination of new exemplars of wading birds and owls and new species of owls, all $p < .01$, but not new species of owls, $p > .10$. No other main effects or interactions were significant.

Discussion

As demonstrated by their post-test performance on the same/different task, participants showed an improved ability to discriminate the training images in *both* the basic and subordinate level category training conditions. Regardless of the categorization task, repeated exposure to the same training stimuli improved participants' discrimination of the birds at the species level. However, subordinate level training produced greater post-test gains in species discrimination relative to basic level training. This finding was not surprising given that subordinate level learning required that participants differentiate the training images at the species level of classification.

As one test of perceptual transfer, it was found that new images of previously learned species were better discriminated if the birds were classified at the subordinate level than at the basic level. For example, participants who were trained to categorize a bird as a "screech owl" were better able to discriminate never-before-seen images of screech owls than participants who learned to classify this bird at the basic level of "owl". Subordinate level training promoted a perceptual strategy that was applicable to new category instances and not limited to the specific images used in training. In a second test of perceptual transfer, it was found that subordinate level knowledge also enhanced the discrimination of exemplars from completely unfamiliar bird species. For example, participants who learned to categorize wading birds, such as green herons, American bitterns, limpkins at the subordinate level were better able to differentiate completely novel species of wading birds, such as whooping crane and snowy egret. These results indicate that subordinate level training promoted two types of perceptual transfer; first, to the recognition of new instances of existing category representations and second, to the discrimination of new instances from novel species categories.

These results highlight a important distinction between simple perceptual exposure and perceptual experience. In this study, participants were exposed to owls and wading birds an equal number of times. Yet, their cognitive *experience* of those perceptual events were profoundly influenced by the categorized task (Schyns, 1998). Where past studies have shown that subordinate level knowledge provides a reliable indicator of extant perceptual expertise, the current study demonstrates that subordinate level training is also useful for facilitating the development of perceptual expertise. By virtue of its perceptual specificity, subordinate level training requires that participants attend to properties of an object's shape and color at a level of detail that is more fine-grained than is required for basic level judgments (Jolicoeur, Gluck, & Kosslyn, 1984). As a consequence of subordinate level learning, flexible object representations (Edelman & Bülthoff, 1992; Tarr & Pinker, 1990)are formed that are robust enough to facilitate the discrimination of novel exemplars from familiar categories and morphologically similar categories. Beyond facilitating general perceptual abilities and attentional strategies, subordinate level training selectively tuned participants' perceptions of color, shape and texture cues that was specific to species in either the owl or wading bird family.

The basic (family) and subordinate (species) level categorization strategies emphasized in this study parallel the strategies typically applied by novices and experts in the real world. Whereas bird novices tend to classify birds at the basic level of "bird" thereby ignoring detailed perceptual information, bird experts recognize birds at subordinate levels of abstraction and are keenly attuned to the visual features that distinguish different species of birds. Moreover, given their subordinate level knowledge and experience, experts can readily incorporate new instances into their representations of existing object categories such that the owl expert can identify a familiar species of owl across different exemplars and changes in viewpoints. Subordinate level knowledge also provides a mechanism for acquiring new subordinate level category representations. Cognizant about the perceptual features that distinguish familiar species of owls, the owl expert, for example, is sensitive to the visual features that signal a new, unfamiliar species category. Thus, the expert holds an advantage over the novice not only with regards to the recognition of objects from familiar categories but also in terms of acquiring new object categories.

The distinction between basic and subordinate level categorization and its role in perceptual expertise has also been explored at the neurophysiological level. Using event-related potentials (ERPs), it was found that when participants categorize objects at the subordinate levels of abstraction, an enhanced negative brain potential is produced approximately 170 ms after stimulus onset (N170) in the posterior recording sites (J. Tanaka, Luu, Weisbrod, & Kiefer, 1999). Similarly, bird , dog, and car experts displayed the enhanced N170 component when categorizing objects in their domain of expertise relative to when categorizing objects outside their domain of expertise (Gauthier, Curran, Curby, & Collins, 2003; J W Tanaka & Curran, 2001). Categorical training of novel visual objects can produce similar N170 enhancement (Curran, Tanaka, & Weiskopf, 2002). Neuroimaging results has shown that the middle temporal region of the brain, the area referred to as the fusiform gyrus, is particularly activated during subordinate level categorization (Gauthier, Anderson, Tarr, Skudlarski, & Gore, 1997). This same brain area is activated when laboratory trained experts (Gauthier, Tarr, Anderson, Skudlarksi, & Gore, 1999) and real world experts (Gauthier, Skudlarski, Gore, & Anderson, 2000)view objects in their domain of expertise. The converging neurological evidence indicates that specific brain processes are engaged during subordinate level object categorization and these same neural mechanisms are recruited for purposes of perceptual expertise.

The kind of perceptual expertise explored in the current study can be contrasted to other forms of perceptual learning. Whereas perceptual expertise studies examine mechanisms underlying complex object recognition, experiments in perceptual learning focus on the discrimination of low-level visual properties, such as the line orientation or color (Ahissar & Hochestein, 1998; Ahissar & Hochstein, 1997). Whereas perceptual expertise accrues over years of real world experience (Johnson & Mervis, 1997; J.W. Tanaka & Taylor, 1991) or during concentrated training in the laboratory (Gauthier & Tarr, 1997; Gauthier et al., 1998) perceptual learning can be acquired quickly (Ahissar & Hochestein, 1998; Ahissar & Hochstein, 1997) and without awareness (Watanabe, Nanez, & Sasaki, 2001). Moreover, perceptual learning shows restricted transfer to the hyper-specific conditions of training (Ahissar & Hochestein, 1998; Ahissar & Hochstein, 1997) whereas perceptual expertise is characterized by its robustness and generalization to new contexts as demonstrated by this study and others (Gauthier et al., 1998).

In conclusion, this study demonstrates that frequent exposure to a particular class of stimuli alone is not sufficient to achieve perceptual expertise. Rather, the acquisition of perceptual expertise depends on the rapid classification of objects at specific, subordinate levels. Perceptual experts are distinguished from novices not only in their ability to recognize familiar stimuli, but also in their ability to integrate novel stimuli into established perceptual categories and to create new category representations when confronted with new information.

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Table 1.

	Training Session				
	Day 2	**Day 3**	**Day 4**	**Day 5**	**Day 6**
Task: Verification					
Basic	942	767	715	667	664
Subordinate	1389	1054	883	781	746
Task: Verification with Deadline					
Basic	---	596	557	500	496
Subordinate	---	842	731	659	582
Task: Picture Matching					
Basic	---	647	621	630	637
Subordinate	---	1095	906	851	839

Table 2.

	Subordinate Level		**Basic Level**	
	Day 1	**Day 7**	**Day 1**	**Day 7**
Wading Birds	1.87	4.02	1.62	2.07
Owls	1.87	4.24	1.69	2.35
Means	1.87	4.13	1.66	2.21

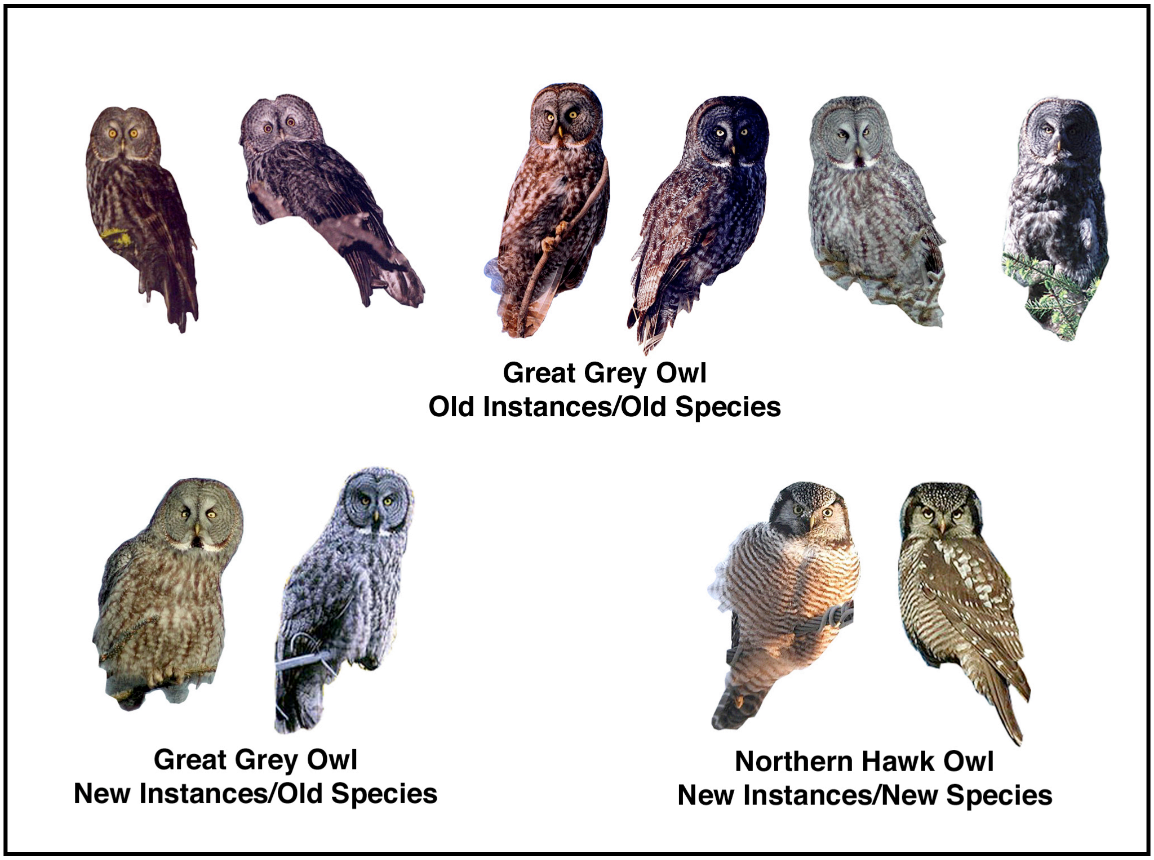
Table 3.

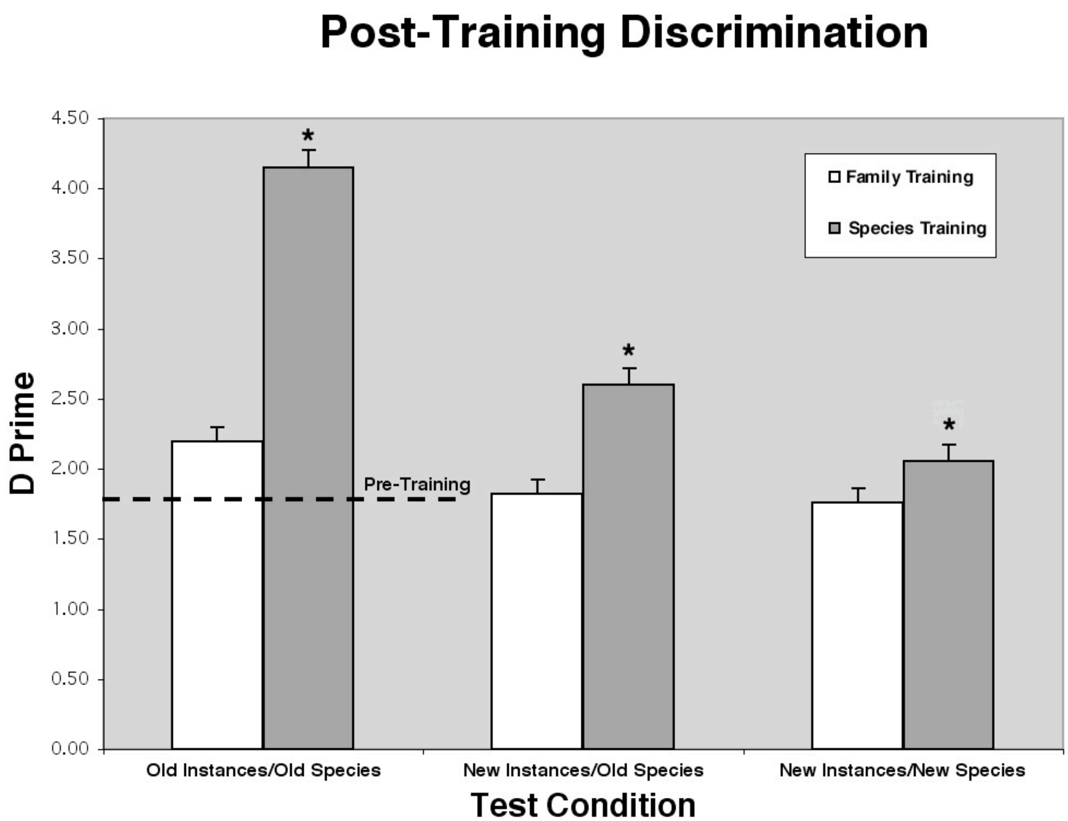
	Subordinate Level		Basic Level	
	New Exemplars	**New Species**	**New Exemplars**	**New Species**
Wading Birds	2.37	2.24	1.84	1.87
Owls	2.81	1.90	1.85	1.67
Means	2.59	2.07	1.85	1.77

Figure Captions

Figure 1. Examples of the Great Grey owl used in the Old instance/Old species condition (top), New instance/Old species condition (bottom left) and the Northern Haw owl employed in New instance/New species (bottom right).

Figure 2. Mean *d'* scores on the post-training discrimination task after family and species level training in the Old instance/Old species, New instance/Old species and New instance/New species test conditions. Dotted line indicates pre-training baseline in the Old instances/Old species condition.


Great Grey Owl
Old Instances/Old Species
Great Grey Owl
New Instances/Old Species
Northern Hawk Owl
New Instances/New Species


Post-Training Discrimination
D Prime
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Pre-Training
Family Training
Species Training
Old Instances/Old Species
New Instances/Old Species
New Instances/New Species
Test Condition