

Do separate processes identify objects as exemplars versus members of basic-level categories? Evidence from hemispheric specialization

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Abstract

When an object is identified as a specific exemplar, is it analyzed differently than when it is identified at the basic level? On the basis of a previous theory, we predicted that the left hemisphere (LH) is specialized for classifying objects at the basic level and the right hemisphere (RH) is specialized for classifying objects as specific exemplars. To test this prediction, participants were asked to view lateralized pictures of animals, artifacts, and faces of famous people; immediately after each picture was presented, a label was read aloud by the computer, and the participants decided whether the label was correct for that picture. A label could name the object at either the basic level (e.g., bird) or as an exemplar (e.g., robin). As predicted, we found that basic-level labels were matched faster when pictures were presented in the right visual field (and hence encoded initially in the LH), whereas exemplar labels were matched faster when pictures were presented in the left visual field (and hence encoded initially in the RH).

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1. Introduction

Every object belongs to more than a single category (Brown, 1958; Rosch, 1975; Smith & Medin, 1981), but people must select only one when they are asked to name an object. Rosch (1975) provided evidence that people spontaneously classify objects at an intermediate level of abstraction, which she called the “basic” level. Identifying a chair as a “chair” instead of as a “folding chair” is sufficient for most of our interactions with the object, notably sitting; identifying it more abstractly, as “furniture,” would not be useful (given that not all furniture can be sat upon) nor would identifying it more specifically, as “folding chair” (given that the additional detail is superfluous for the task at hand).

However, people do not always name objects at the basic level. For example, although a canary is named “bird,” a “penguin” is named “penguin,” not “bird.”

The basic-level category is most applicable for a typical member of the category, whereas the subordinate term is spontaneously applied to atypical members of the category. Jolicoeur, Gluck, and Kosslyn (1984) distinguish between the basic-level and the “entry-level” term; the entry-level term is the one spontaneously applied when naming an object, including objects that are atypical for their basic-level categories. Objects named with the same basic-level term tend to be perceptually similar, primarily in terms of shape (Rosch, 1975). In contrast, members of a category that have atypical shapes are often named as specific exemplars. An “exemplar” is more specific than the entry level category and can be represented by a single instance.

In this article we investigate whether distinct perceptual processes are used when one classifies an object at the basic-level versus as an exemplar. Consider an analogous situation, where one encodes spatial relations either in terms of a relatively large equivalence class (i.e., a category, such as “above” or “in front of”) or in terms of the specific metric information. In order to encode the categorical information, one must discard the very

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information that needs to be preserved to encode the metric information. This observation suggests that two distinct mechanisms may be at work, and in fact ample evidence now indicates that this is the case (e.g., see Chabris & Kosslyn, 1998; Hellige & Michimata, 1989; Kosslyn, 1987; Kosslyn, Sokolov, & Chen, 1989; Laeng, 1994; see for reviews: Jager & Postma, 2003; Laeng, Chabris, & Kosslyn, 2003).

Similarly, when classifying an object at the basic level, one apparently needs to ignore the very information that is required to distinguish individual exemplars (cf. Edelman & Duvdevani-Bar, 1997; Jacobs & Kosslyn, 1994; Price & Humphreys, 1989). We propose that the brain may opt for a division of labor when classifying objects at the basic-level versus as exemplars. However, this reasoning does not guarantee that the brain operates this way. In fact, several simulation studies (e.g., Hummel & Stankiewicz, 1998; Johnston & McClelland, 1974; McClelland & Rumelhart, 1985) have shown that a single network trained to distinguish exemplars can develop, as an emergent property, sensitivity to the commonalities among similar exemplars. Thus, in principle, the learning of categories could actually benefit from learning and processing similar exemplars in a unitary system.

Although models clearly demonstrate that a single network can in principle process both categories and exemplars, they do not show that the brain must operate in such a way. One crucial question is not whether in principle a single network could process both basic-level and exemplar-level naming, but whether such unitary systems perform these tasks more effectively than do separate, specialized systems. Simulations with artificial networks have demonstrated that non-unitary systems can be more efficient than unitary ones. For example, in one simulation (Kosslyn, Chabris, Marsolek, & Koenig, 1992), the concurrent processing of different types of input/output mappings was compared in a unitary system versus segregated subsystems. The findings supported the intuition that segregated processing is—under at least some conditions—more efficient than a single massive system (see also Jacobs & Kosslyn, 1994). Two systems can be more efficient than one if they compute in parallel different input/output mappings—particularly when what is valuable information for one system may be noise for another.

Another critical question is whether the brain is always optimized. Even if it is computationally most effective to compute information in a specific way, the brain may not have evolved to be as efficient as possible (perhaps because of structural constraints of the sort discussed by Gould & Lewontin (1979)). We cannot determine with certainty how the brain processes information by analysis of modeling alone; we must conduct empirical research on the brain itself. In sum, the present research was designed to distinguish between

two general classes of models. On the one hand, the brain may use two distinct mechanisms to encode shape, one that attempts to categorize objects as members of basic-level categories (e.g., apples, dogs, or cars) and one that labels specific exemplars. On the other hand, a single system could categorize objects in both ways. Neuropsychological data can play a decisive role in documenting the existence of distinct mechanisms that underlie different processes (Caramazza, 1992; Kosslyn, 1994; Shallice, 1988). Essentially, if it can be demonstrated that different parts of the brain are crucial for one process but not another, we gain confidence that the underlying mechanisms are indeed different (Teuber, 1955). Perhaps the simplest example of this approach relies on showing that the cerebral hemispheres differ in their ease of carrying out different processes. That is, if the left hemisphere performs one process better than the right, and the right performs another process better than the left, these findings would be consistent with the view the two processes rely on distinct underlying mechanisms. If the same mechanism were used in both cases, we might expect that either one hemisphere would perform both processes better or that there would be no difference between the hemispheres.

Indeed, recent neuropsychological findings are consistent with the hypothesis that the brain uses different mechanisms to identify members of basic-level categories than to identify exemplars. Specifically, researchers have shown that the left hemisphere (LH) preferentially encodes prototypes, whereas the right hemisphere (RH) preferentially encodes exemplars (e.g., Marsolek, 1995). Because it is, by definition, a very typical member of a basic-level category, a representation of a prototype will be classified at the basic level. Exemplars that differ significantly from a typical member of the category will be classified as exemplars. Marsolek (1995), basing his work on the classic study of Posner and Keele (1968), distorted a meaningless, ideogram-like, two-dimensional form to produce a set of exemplars. The participants were initially trained to categorize the distortions into separate classes. Subsequently, they were tested for their recognition of the previously seen forms in each visual hemifield as well as for the previously unseen central tendency (prototype) and entirely novel distortions. Marsolek found that the participants recognized the prototypes of each category better when they were presented in the right visual field, directly to the LH; in contrast, the participants recognized the “old” studied specific forms better than they were presented in the left visual field, directly to the RH. Thus, separate neural systems, which functioned better in different hemispheres, encoded the central tendencies of patterns versus specific instances. Findings from other divided-visual-field studies converge on the distinction between a LH-based category encoding subsystem and a RH-based exemplar encoding subsystem (e.g., Kosslyn,

1994; Marsolek, 1995; Marsolek, Kosslyn, & Squire, 1992; Marsolek, Schacter, & Nicholas, 1996; Marsolek, Squire, Kosslyn, & Lulenski, 1994). To our knowledge, in those studies where both subordinate and basic labels have been used, the opposite pattern of results (i.e., a reversed labels-by-visual-field interaction) has never been observed.

However, most divided-visual-field studies of object identification have focused on either spontaneous naming (i.e., entry-level identification) or on matching rehearsed basic-level labels to stimuli presented in each visual field. The findings from these studies are ambiguous. Some studies have found a right visual field (LH) advantage (e.g., Wyke & Ettliger, 1961; Bryden & Rainey, 1963), but some have reported a left visual field (RH) advantage (e.g., McAuliffe & Knowlton, 2001; Schmuller & Goodman, 1980). Vitkovitch and Underwood (1991, 1992) found a right visual field (LH) advantage for matching pictures to superordinate labels (e.g., animal, fruit). Null findings are the most common result of divided-visual-field studies of entry-level object naming (e.g., Paivio & Ernest, 1971; Young & Bion, 1981; Levine & Banich, 1982; Sergent & Lorber, 1983; Biederman & Cooper, 1991; Humphrey & Jolicoeur, 1993). However, null findings are common in divided-visual-field studies with normal participants. The divided-visual-field method relies on detecting small differences (often a few milliseconds between the visual fields) in spite of typically low statistical power (due to variability arising from individual differences). Hence, null findings could reflect many nuisance factors instead of the absence of hemisphere-specific effects. Indeed, when meta-analysis techniques have been applied to the corpus of divided-visual-field studies within a specific domain (e.g., encoding spatial relations; see Laeng et al., 2003), clear hemisphere-based dissociations have emerged.

More recently, several neuroimaging studies have tracked neural activity while participants either spontaneously named stimuli or decided whether names (at the entry-level) could be appropriate labels for pictures of individual objects. In a PET study, Damasio, Grabowski, Tranel, Hichwa, and Damasio (1996) found that pictures of animals, artifacts, and people all activated (separate) areas within the temporal lobe of the LH. Perani and colleagues (1995), as well as Martin, Wiggs, Ungerleider, and Haxby (1996) found that naming pictures of animals and tools activated areas of the LH's temporal lobe. Other studies involving naming of visual stimuli have shown similar findings (see Sergent, Ohta, & MacDonald, 1992; Moscovitch, Kapur, Köhler, & Houle, 1995; Price, Moore, Humphrey, Frackowiak, & Friston, 1996; Moore & Price, 1997; Rosier et al., 1997; Zelcovicz, Herbster, Nebes, Mintun, & Becker, 1998). Seger et al. (2000) examined the change in hemispheric asymmetry, as measured by functional-MRI (fMRI), during visual concept learning. They

specifically hypothesized that the cerebral hemispheres play different roles in the development of categorical expertise; namely, they proposed that the RH specializes in processing specific stimuli, whereas the LH specializes in processing patterns abstracted across specific stimuli. Neuroimaging was conducted while the participants learned to classify stimuli resembling abstract paintings in two categories (Jones's and Smith's art). In the initial phases of learning, Seger et al. found only RH activation. However, the LH was progressively engaged with training, but only for those participants who actually learned to perform the categorization. The authors interpret these findings as evidence that the LH is specialized for learning abstract categories.

For present purposes, the most interesting neuroimaging studies are those that asked participants to evaluate subordinate, basic, and superordinate labels in picture-name verification tasks (e.g., Gauthier, Anderson, Tarr, Skudlarski, & Gore, 1997; Gauthier et al., 2000; Kosslyn, Alpert, & Thompson, 1995; Koutstaal et al., 2001; Op de Beeck, B atse, Wagemans, Sunaert, & Van Hecke, 2000). For example, Gauthier and colleagues (1997) asked participants to perform a picture-name verification task in which basic-level or exemplar names were presented. When they subtracted the activations in the basic-level name condition from those in exemplar name condition, Gauthier and colleagues found greater activation of the fusiform and inferior temporal gyri in the RH than in the LH. They concluded that the RH activation reflected the additional perceptual processing necessary to verify an exemplar label. The results from these studies support the idea that separate perceptual systems are used to classify an object at the basic-level versus as an exemplar. The results revealed activation in both hemispheres, but some of the activation was clearly lateralized to the left or right side. Just given such data, however, it is impossible to know whether any of these lateralized areas function more efficiently in one condition or another.

Thus, in the present study we presented visual stimuli tachistoscopically in one of the two lateral visual hemifields while participants maintained central fixation. Only the contralateral hemisphere will initially process stimuli seen in only one visual field, and hence the participants will be faster or more accurate if this hemisphere is better able to perform the task (for details on this logic, see Hellige, 1993; Springer & Deutsch, 1998). We used a picture-name verification task, in which the name of an object was read aloud (by the computer) after each picture, and the participants decided whether the name was appropriate for that object (half the time it was, half the time it was not). Critically, some words correctly named the object at the basic-level (e.g., "car") and some as an exemplar (e.g., "convertible"). If our hypothesis is correct, participants should evaluate basic-level names better when the pictures are

presented initially to the LH, and exemplar names better when the pictures are presented initially to the RH.

2. Method

2.1. Participants

Forty-seven Harvard University undergraduates (20 male, 27 female) volunteered to participate for pay. Only right-handed participants were recruited and their handedness was confirmed by their scores on the Edinburgh Handedness Inventory (Oldfield, 1971).

2.2. Apparatus and materials

Visual stimuli were presented on the screen of a Macintosh Quadra computer and auditory stimuli were played through its speakers. MacLab software controlled the presentation times and recorded the participant's key press and response time (from the onset of the picture) on each trial. The B key was relabeled 'Yes' and the N key was labeled 'No.' All participants used two fingers of their right, preferred hand, for responses.

Twelve different sets of black-and-white drawings of animals and artifacts as well as 12 photos of faces were selected as stimuli. The drawings were assembled from different sources, such as zoology books (e.g., Buffon, 1993; Harter, 1979) and the MacMillan Visual Dictionary (Corbeil & Archambault, 1995), and were all realistic depictions (either engravings or fine ink pen drawings) in which the correct proportions, natural texture, and shading of the animals' bodies were clearly represented. Each drawing depicted the animal in a "conventional" view; that is a side view for all animals except the beetles (depicted from the top). The cars were also shown in side views, but the pictures of chairs showed these in their "canonical" 3/4 view (cf., Palmer, Rosch, & Chase, 1981). Faces of celebrities were clipped out of magazines and a book of portrait photography (Karsch, 1996). These faces could appear in either a full frontal or 3/4 pose.

All pictures were digitized with a Microtek Scanner 600ZS and then edited with Adobe Photoshop to normalize the size to 5 cm along the object's principal axis. The faces appeared on a uniform, solid gray background. Two mirror versions of each stimulus were created so that, in either visual field presentation, the front side of each object (e.g., the head for an animal or the front wheels for a car) was oriented towards the central fixation point. Each picture's center was placed at 6 cm from the central fixation point. Participants sat at a distance of 55 cm from the screen. Although part of each image would thus fall within the foveal region, researchers have shown that laterality effects are present even when stimuli are presented within one side of the

fovea (Lavidor & Ellis, 2003). Each name was recorded with SoundEdit software, pronounced slowly and clearly by a female voice.

We grouped three different objects (or people for the photographs) into each set. To produce incorrect basic-level labels, we yoked pairs of sets; for example, the "glasses" set was paired with the "shoes" set, so that on an incorrect trial the participant could see a wine glass but hear the word "shoe." To produce incorrect exemplar labels, we used incorrect labels from the same basic-level category (e.g., a champagne glass was seen, but either "burgundy" or "port" was heard). Fig. 1 shows examples of the visual stimuli. We expected many participants to be unfamiliar with the exemplar names of some objects; therefore, all participants rehearsed all the names prior to testing. Indeed, for the beetles we used the names of three of the American states (i.e., Idaho, Nevada, and Montana) instead of the authentic names (which were long Latin zoological terms). The sets were yoked as follows: (1) Dogs (collie, greyhound, pointer) and Beetles (Idaho, Nevada, and Montana); (2) Cows (Ayrshire, Holstein, Jersey) and Rodents (gopher, rat, squirrel); (3) Birds (falcon, parrot, robin) and Shells (Cassis, Dolium, Pomus); (4) Glasses (burgundy, champagne, port) and shoes (chukka, loafer, oxford); (5) Cars (convertible, hatchback, pick-up truck) and chairs (cabriolet, rocking, Wassily); (6) Men (Bogart, Bill Clinton, Einstein) and Women (Hillary Clinton, Marilyn Monroe, Streisand; note that we treated "men" and "women" as the basic-level terms for the faces). The pairings respected the basic ontological distinction between natural kinds, artifacts, and persons.

2.3. Procedure

The visual stimuli appeared on a 14 in. computer screen located 50 cm from a chin rest. Each session consisted of four blocks of trials. Participants first received the faces, then the animal sets, and finally the artifacts sets. Before each block the participants received a familiarization phase in which we asked them to memorize the two sets of visual stimuli and the associated words. The participants saw each picture for that block on separate pieces of paper, with the appropriate exemplar name appearing below (in Geneva 26 font). The participants could spend as much time as they wished viewing the material, but none took any longer than two minutes to memorize the stimuli prior to a set of trials.

Before each block of trials, the participants were told that they would see the drawings and hear the names of the objects just memorized, but that the pictures would appear very quickly while they maintained fixation on a small cross at the center of the screen. The participants' job was to determine whether the name was appropriate for the immediately preceding object. Each trial had the

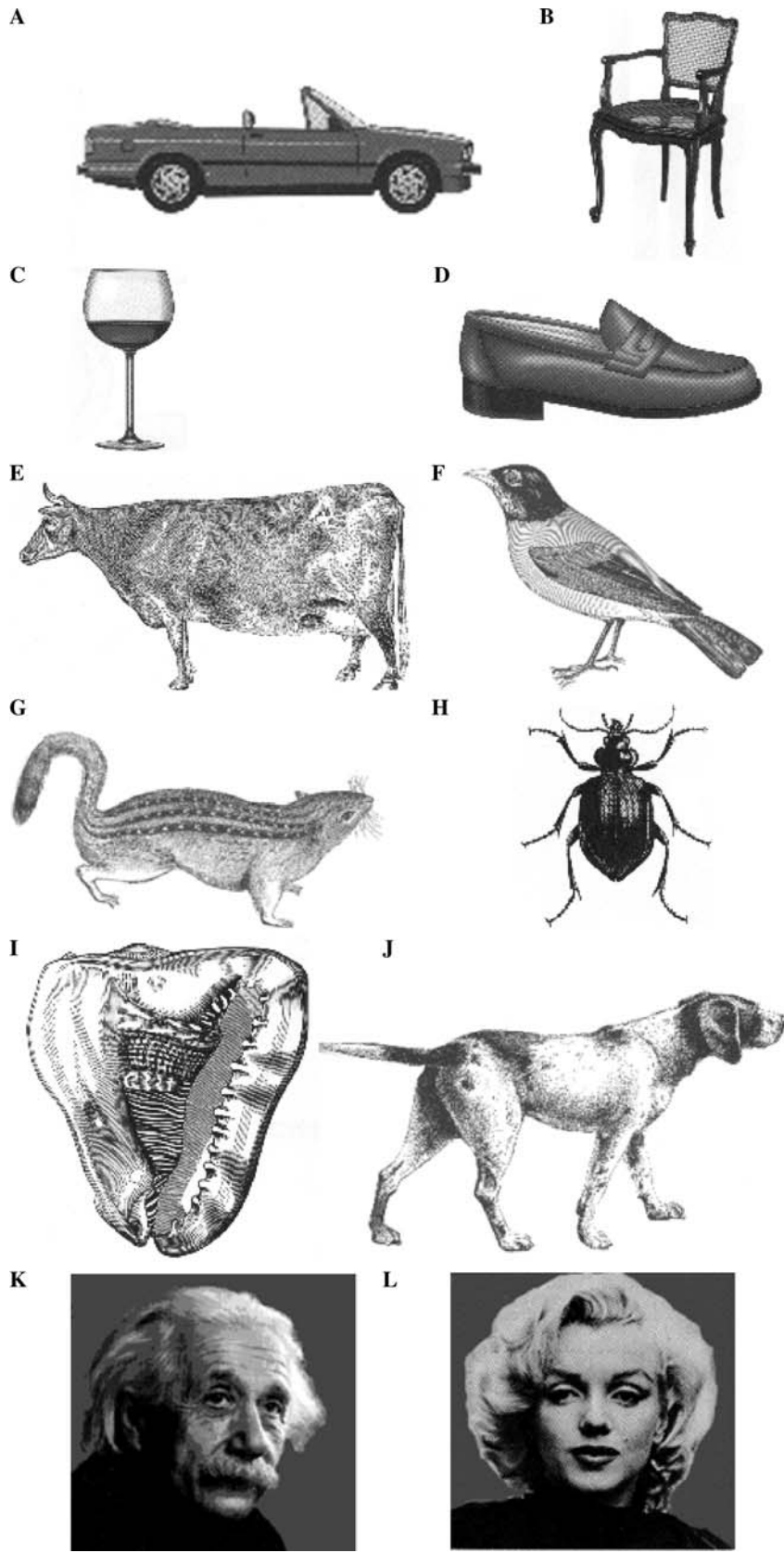


Fig. 1. Examples of stimuli used in the experiment. Each drawing is from one of the different basic classes: (A) car (convertible); (B) chair (cabriolet); (C) glass (burgundy); (D) shoe (oxford); (E) cow (ayrshire); (F) bird (robin); (G) rodent (squirrel); (H) beetle (montana); (I) shell (cassis); (J) dog (pointer); (K) man (Einstein); (L) woman (Marilyn).

following sequence of events: (1) a blank screen; the participants were to begin a trial by pressing the space bar of the computer's keyboard; (2) a small fixation cross would then appear at the center of screen, which remained visible for 450 ms; the participants were asked to gaze directly at the cross and to maintain fixation until the end of the trial; (3) a lateralized visual stimulus would appear for 100 ms; (4) a blank screen appeared at the same time that a recorded name was played through the computer's speakers; (5) the participants were to press, as quickly and accurately possible, one of two adjacent keys marked "yes" and "no" to indicate whether the word was an appropriate name for the pictured object. Following this, the participant would again press the space bar to initiate a new trial. The computer recorded which key was pressed in each trial and the RT from the offset of the name to the participant's key press.

In every block, each picture was shown 16 times. On eight of these trials the picture was presented directly to the LH and on the other eight it was presented directly to the RH. On four of these lateralized trials the picture was paired with a basic-level word and on the other four trials with an exemplar-level word. In two of these trials the basic-level or exemplar-level word correctly named the picture, whereas on the other two trials the word named an incorrect exemplar or class. Thus, each participant evaluated 96 trials in each block, which were arranged in pseudo-random order (i.e., random except that no more than three consecutive trials had the same label, response, or visual field). The complete experiment consisted of 576 trials.

Finally, we asked 10 additional participants to rate the typicality of each item (cf. Rosch, 1973). The three items in each class were shown on the same page. The pictures were arranged in a column on the left side, and a blank line appeared to the right of each picture. The participants were asked to write a number ranging from 1 to 5 (i.e., from least to most typical) on each line, indicating how typical the picture was for that category.

3. Results

We first calculated descriptive statistics for each participant, obtaining a mean response time (RT) and error rate for each combination of the variables Class (e.g., glass versus shoe), Label (exemplar versus basic-level), and Hemisphere (left versus right). RTs from trials on which errors occurred were excluded from analyses of the RTs, and trials with RTs greater than three standard deviations from each individual's mean RT for that cell were treated as outliers and excluded from all subsequent analyses. Preliminary analyses revealed no main effect of, or interactions with, the sex of the participant or the type of response (Yes/No), and

thus we pooled over these factors in the analysis presented below.

3.1. Analyses by participants

We first performed a repeated-measures analysis of variance with Class (animals, artifacts, faces), Label (exemplar versus basic-level), and Hemisphere (LH versus RH) as the within-participants variables and RTs as the dependent variable. Most importantly, this analysis revealed the predicted interaction between Label and Hemisphere, $F(1, 46) = 35.7$, $p < .0001$. As expected, the participants evaluated basic-level names faster when pictures were presented initially to the LH (mean RT = 884 ms; $SD = 131$ versus mean RT = 900 ms; $SD = 126$ for the RH) and evaluated exemplar names faster when pictures were presented initially to the RH (mean RT = 1020 ms; $SD = 143$; versus mean RT = 1047 ms; $SD = 152$ for the LH). Fig. 2 illustrates this result for each class of stimuli. Individual t tests confirmed the hemisphere differences: basic-level label: $t(46) = 2.9$, $p < .007$; exemplar label $t(46) = -4.9$, $p < .001$.

We also found that basic-level labels generally were verified faster (mean RT = 892 ms; $SD = 128$) than subordinate labels (mean RT = 1034 ms; $SD = 148$), $F(1, 46) = 275.6$, $p < .0001$. However, there was no difference between the hemispheres in general, $F(1, 46) = 1.7$, $p > .1$. There was, however, also an overall difference in RTs among the three classes, $F(2, 92) = 15.8$, $p < .0001$. As revealed by Dunn's post hoc t' tests, labels for objects (mean RT = 924 ms; $SD = 162$) were verified faster than faces' labels (mean RT = 965 ms; $SD = 164$), $t'(46) = 2.7$, $p < .05$, and animals' labels (mean RT = 1000 ms; $SD = 247$), $t'(46) = 5.1$, $p < .01$; in addition, the difference in speed between verifying faces' and animals' labels approached significance, $t'(46) = 2.3$, $p < .07$. Notably, there was no three-way interaction between the factors of Class, Hemisphere, and Label, $F(2, 92) = 0.1$, $p > .1$.

In addition, we performed a repeated-measures analysis of variance with Class (animals, artifacts, faces), Label (exemplar versus basic-level), and Hemisphere (LH versus RH) as the within-participants variables and % Errors as the dependent variable. This analysis also revealed the predicted interaction between Label and Hemisphere, $F(1, 46) = 18.6$, $p < .0001$. A t test showed that participants evaluated subordinate-level names more accurately when pictures were presented initially to the RH (mean % Error = 3.9; $SD = 5.5$) than to the LH (mean % Error = 6.9; $SD = 6.7$). However, we did not find a hemisphere difference in error rate for basic-level labels (RH: mean % Error = 3.6; $SD = 4.8$; LH: mean % Error = 3.9; $SD = 4.3$). Moreover, basic-level labels were verified more accurately (mean % Error = 3.8 ms; $SD = 4.6$) than subordinate labels (mean %

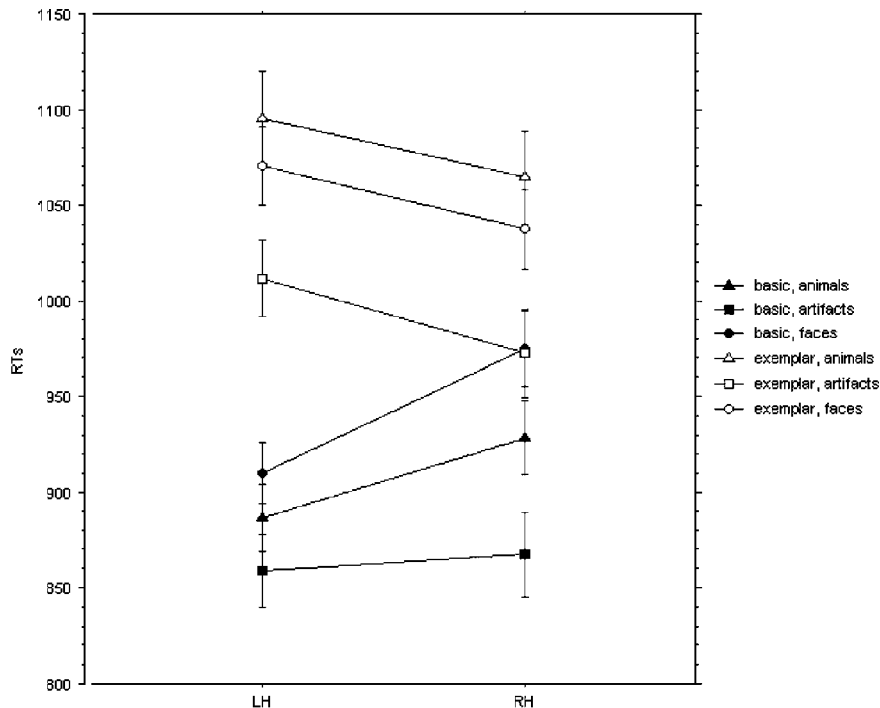


Fig. 2. Means (symbols) and SEs (bars) of response times (RTs) to stimuli in each class (animals, artifacts, and faces) when matching a basic or subordinate label to a picture seen initially by the left (LH) and right hemisphere (RH).

Error = 5.4 ms; $SD = 6.3$), $F(1, 46) = 8.9$, $p < .004$. Again, the hemispheres performed comparably overall, and the participants evaluated the different classes equally accurately; in addition, there was no interaction between these factors any others, $p > .1$ in all cases.

3.2. Analyses by items

We also performed analyses by items in order to assess the possible contribution of confounding variables on the hypothesized effects. First, there is the possibility that the hemisphere effects we found might simply reflect the LH's access to familiar words or pictures whereas the RH may have better access to unfamiliar words or pictures (i.e., recently learned material). Indeed, several divided-visual-field studies have shown a RH advantage for newly learned material and a LH advantage for familiar items (e.g., Goldberg & Costa, 1981; Laeng & Rouw, 2001; Marzi & Berlucchi, 1977; Umiltà, Brizzolara, Tabossi, & Fairweather, 1978). Similarly, neuroimaging studies have shown initial engagement of RH structures with the encoding of novel stimuli followed by the progressive recruitment of LH structures with increased familiarity (e.g., Seger et al., 2000; but see also Nyberg, Cabeza, & Tulving, 1996).

To investigate the possibility that our results reflect differences in familiarity with the stimuli, we performed ANOVAs after obtaining means for each item, pooling over participants; these analyses included Label (basic-level versus subordinate) and Hemisphere (LH versus

RH) as the within-item variables and RTs as the dependent variable. We also included the items' Familiarity (familiar versus novel) as a between-items factor. That is, we grouped those items that were familiar to the participants (i.e., birds, cars, dogs, faces, and rodents) at the outset of the experiment versus those items that they had to learn at the outset (i.e., beetles, chairs, cows, glasses, shells, and shoes). Note that this grouping applies to both the visual and verbal familiarity of each item. This analysis revealed the expected interaction of Hemisphere and Label, $F(1, 28) = 5.9$, $p = .02$, confirming a LH advantage for matching basic-level labels (LH: mean RT = 918, $SD = 63$; RH: mean RT = 938, $SD = 74$) and a RH advantage for matching subordinate labels (LH: mean RT = 1070, $SD = 134$; RH: mean RT = 1032, $SD = 95$). We did not find a difference between familiar and unfamiliar items, $F(1, 28) = 1.3$, $p = .27$. However, the interaction of Hemisphere and Familiarity approached significance, $F(1, 28) = 3.7$, $p = .07$; unfamiliar items tended to be processed faster by the RH (mean RT = 994, $SD = 108$) than the LH (mean RT = 1030, $SD = 158$). Most importantly, the interaction of Hemisphere by Label by Familiarity did not even approach significance, $F < 1$.

When the same ANOVA was performed on the % Error rates as the dependent variable, we again found an interaction of Hemisphere and Label, $F(1, 28) = 4.3$, $p = .05$. Specifically, there was no hemisphere difference for basic-level labels (LH: mean % Error = 3.4, $SD = 1.6$; RH: mean % Error = 3.4, $SD = 3.1$) but a

clear RH advantage for subordinate level labels (LH: mean % Error = 7.0, $SD = 5.6$; RH: mean % Error = 4.2, $SD = 4.6$). Again, we did not find an effect of Familiarity, $F(1,28) = 1.3$, $p = .15$, or interactions with Hemisphere, $F < 1$, or Hemisphere and Label, $F < 1$. In short, our previously observed effects of level cannot be ascribed to a confound with differences in familiarity.

Another possible account of the hemisphere effects we observed might appeal to the notion that the LH is adept at easy verification, not basic-level picture processing, whereas the RH is adept at difficult verifications, and not exemplar level picture processing (cf. Underwood & Whitfield, 1985). In order to evaluate this possible interpretation, we performed another repeated-measures ANOVA by items with Hemisphere and Label as factors and Task Difficulty as an additional factor. To obtain the latter variable we computed the median of the basic-level error percentages and we divided items in two groups, Easy or Difficult, according to whether their error rates fell either below or above the median. This ANOVA showed that the Label-by-Hemisphere interaction cannot be accounted for by task difficulty. Not only did the interaction remained intact, $F(1,28) = 6.85$, $p = .01$, it was also present at both levels of difficulty; moreover, Task Difficulty did not interact with Hemisphere or any of the other factors, $0.5 < F < 1.0$.

Another objection that could be raised to the present findings is that the hemisphere effects might have occurred because the LH is adept at categorizing typical items whereas the RH is adept at categorizing atypical items, and not exemplar-level picture processing per se (cf. Zaidel, 1987; but see also Vitkovitch & Underwood, 1991). We used the typicality ratings obtained from the 10 independent judges to divide items into three groups: Low (ratings between 1 and 2.5; $N = 10$), Medium (ratings between 2.5 and 3.5; $N = 11$) and High (ratings between 3.5 and 5; $N = 15$). Only 22% of the items were judged as less typical than the midpoint (3) on the scale. Two items received an average score of 5 (i.e., they were judged highest in typicality by every judge). In contrast, the lowest average typicality score for an item was 1.8. We performed a separate repeated-measures ANOVA by items with Hemisphere, Label, and Typicality (Low, Medium, High) as factors. The analysis revealed that the Label-by-Hemisphere interaction cannot be accounted for by differences in typicality of the items included in the test: this interaction remained intact, $F(1,28) = 6.73$, $p = .01$, whereas there was no interaction between Typicality and any of the other factors, $0.5 < F < .7$.

Finally, one could also entertain the hypothesis that participants were generally faster for the basic-level labels than subordinate labels simply because subordinate labels are typically longer strings of syllables than basic labels (cf. Biederman, Subramaniam, Bar, Kalocsai, &

Fiser, 1999). Indeed, in our experiment, the subordinate labels had on average 2 syllables ($SD = 1$), whereas the basic-level labels had on average 1.25 syllables ($SD = 0.45$). We performed two separate ANOVAs by item with Label (basic-level versus subordinate) as the within-item variable and RT or mean % Errors as the dependent variable. As an additional factor we used each item's Number of Syllables (1, 2, 3, 4). The ANOVA on RTs showed that the predicted advantage of basic-level versus subordinate labels remained significant in spite of differences in number of syllables, $F(1,25) = 16.3$, $p = .005$. The ANOVA on mean % Errors revealed no effect of number of syllables.

4. Discussion

Participants evaluated basic-level names faster when pictures were presented initially to the LH and evaluated exemplar names faster when pictures were presented initially to the RH. The “basic level” is usually the “entry level” (unless objects are highly atypical), and anything more specific than that can be considered as an exemplar (provided that it can be represented by a single example). We made the counterintuitive prediction that the RH would be better than the LH in matching verbal labels that require accessing the representation of a single instance in a category. In contrast, we made the opposite prediction when a category representation is required, namely that the LH would be better than RH. The findings clearly supported our predictions.

The observed laterality differences are also consistent with the findings of previous studies. For example, in a neuroimaging study, Gauthier and colleagues (1997) found greater activation of the fusiform and inferior temporal gyri in the RH than in the LH when participants matched subordinate labels to pictures. They concluded that the RH activation reflected the additional perceptual processing necessary to verify an exemplar label. Kosslyn, Hamilton, and Bernstein (1995) had also reached the same conclusion in a PET study (see also Koutstaal et al., 2001). Moreover, there is clinical neuropsychological evidence for dissociation between learning visual categories and memory for instances of visual patterns. Remarkably, damage to the RH's temporal lobe, more than to the LH's, disrupts memory for specific pictures of objects and faces (Bowers, Blonder, Feinberg, & Heilman, 1991; Milner, 1968; Phelps & Gazzaniga, 1992; Vilkki, 1987; Warrington, 1984). Metcalfe, Funnell, and Gazzaniga (1995) showed that the RH of split-brain patient J.W. had superior pattern memory than the LH, and they proposed that this RH advantage arose from items that are distinguishable from but in the same class as the targets. Squire and Knowlton (1995) studied an amnesic patient E.P., who had virtually no capacity for explicit memory,

and found that despite E.P.'s inability to memorize exemplars, performance in a categorization of dot patterns (cf., Posner & Keele, 1968) was normal. This patient would recognize a prototype (unseen during learning) as a member of a category (see also Kolodny, 1994; Nosofsky & Zaki, 1998).

Studies of normal participants also provide converging evidence for the inference that separate neural systems underlie the processing of categories and exemplars. Marsolek and colleagues (1992, 1994, 1996) found greater priming for unchanged typographic case when words were presented initially to the RH than to the LH. In contrast, changing the letters' case (e.g., from upper case to lower case) resulted in equivalent levels of priming in both hemispheres. This result is consistent with the idea that the RH encodes specific exemplars better than the LH. In a more recent divided-visual-field study, Marsolek (1999) assessed repetition priming of line drawings of common objects (e.g., a piano), and found that the picture of one exemplar (e.g. a grand piano) primed the picture of another exemplar of the same class more effectively in the LH than in the RH. In contrast, repetition of the same exemplar (e.g., repeating the picture of the same grand piano) had larger priming effects in the RH than in the LH.

One of the findings in our experiment was that basic-level labels were verified faster than exemplar labels. This finding replicates those of many previous studies (e.g., Rosch, Mervis, Gray, Johnson, & Boyes-Braehm, 1976; Smith et al., 1978; Smith & Medin, 1981). This effect could not be ascribed to subordinate labels being longer than basic-level labels: when we took this factor into account, the basic-level advantage persisted and this factor had no influence on laterality differences. In our view, the basic-level advantage may arise because one must encode more perceptual properties to identify an object as an exemplar than as a member of a basic-level category. For example, to classify an object as a piano, only the general shape or perhaps one common detail (e.g., the keyboard) is necessary; in contrast, to classify it as a grand piano, one must also note the distinctive shape of its lid and sounding-board (cf. Jolicoeur et al., 1984; Kosslyn, Maljkovic, Hamilton, Horwitz, & Thompson, 1995).

In the present study, all of the pictures were of relatively typical shapes (i.e., 78% of the items were judged as more typical than the midpoint on a 5-step scale). Not surprisingly, differences in typicality did not influence the visual field differences. If highly atypical items had been included in the task (e.g., a penguin for the bird category) then we might have observed an interaction between item typicality and visual field. In a previous study, Jolicoeur, Gluck and Kosslyn found that objects with atypical shapes for their basic-level category (e.g., penguins, ostriches) were categorized more rapidly as exemplars than as members of the basic-level category (see also Kosslyn

& Chabris, 1990; Murphy & Brownell, 1985, for a review). Our claim that the RH is specialized for encoding exemplars is based on one crucial observation: The representation of an exemplar can be an encoding of a 'single instance' of the object. One could wonder what would have happened, in terms of visual field differences, if we had not included basic level labels at all, and treated 'convertibles' as a class and contrasted this class with specific types of convertibles (e.g., Ferrari convertibles, Toyota convertibles, etc.). In such a case, we surmise that the results would depend on what sorts of representations are accessed in order to perform the task: if accessing a representation of a single instance were sufficient to perform the task, then we would expect that the RH should be better than LH; if a category representation were required, then we would expect this effect to disappear (but note that a category representation for 'convertibles' might only exist for car experts and, indeed, differences in laterality of brain event-related potentials have been observed when comparing experts to novices; cf. Tanaka & Curran, 2001; Rossion, Gauthier, Goffaux, Tarr, & Crommenlinck, 2002). Finally, one could also wonder what would have happened if we had used in our task superordinate (e.g., animal, furniture) instead of basic level labels (bird, chair) labels. We would have also expected a LH advantage, since semantic information about superordinate membership would be accessed more efficiently from the entry-level than the exemplar (Jolicoeur et al., 1995). Interestingly, Vitkovitch and Underwood (1991) did not find an interaction between typicality and visual field when pictures were matched to superordinate labels (e.g., animal), but the overall latencies were faster when stimuli were presented initially to the LH than to the RH.

Another objection that may be raised about the present finding is that the hemisphere effects might indicate that the LH is more adept at familiar items whereas the RH is more adept at unfamiliar ones. Indeed, a LH advantage has been reported when participants process familiar items (e.g., Marzi & Berlucchi, 1977; Umiltà et al., 1978; Goldberg & Costa, 1981; Seger et al., 2000; Laeng & Rouw, 2001). However, we found that familiarity with each item used in our task (either its image or name) could not account for the hemisphere differences we observed. When items were grouped by familiarity, there was no interaction between this variable and the level of categorization or hemisphere. We also note that our finding that the RH is better able to identify exemplars and individual persons allows us to document a double dissociation: Damasio and colleagues (1996) report that an area of the left temporal lobe is critical for accessing proper names (see also Miceli et al., 2000). Thus, our results clearly do not reflect the processes involved in encoding the meanings of the names.

Another possible objection to our account could posit that the differences between basic-level and

subordinate level matches simply indicates that the former were overall easier than the latter. In this view, the critical factor that underlies hemisphere differences in picture-name verification and, possibly, in any lateralized task, would be the difficulty of each of the tasks (cf. Dunn & Kirsner, 1988). In the present study, this view would posit that the RH advantage for subordinate label matches arises from a RH advantage in performing difficult verifications whereas the LH advantage for basic-level verification arises from a LH advantage in performing easy verifications. Moreover, the fact that participants used their right hands to press the keys could have produced a spurious LH advantage for basic-level matching trials where in fact there is no hemisphere-based advantage in visual processing. However, we reject the alternative account sketched above for several reasons. First, when item difficulty was considered as a factor in the statistical analysis, based on the participants' mean % error rate, the original hemisphere effects on RTs persisted and the level of difficulty had no influence on the visual field differences. Indeed, the very idea that a critical factor in causing hemisphere differences is the difficulty of a task is theoretically empty. If task difficulty can be used, post hoc to explain visual field differences, this would still beg the question about the underlying hemisphere-based mechanisms. "Difficulty" is not a simple concept, but rather depends on the nature of processing and the specific requirements of a task. In contrast, a principled theory of hemispheric asymmetry must define in advance which tasks will be comparatively easy or difficult for each hypothesized perceptual mechanism and, in turn, for each hemisphere. Second, several divided-visual-field experiments explicitly manipulated which hand was used to produce responses. In these experiments, participants in one condition responded with their preferred hand whereas those in another condition responded with both hands (counterbalanced across type of response). These studies have reported non-significant interactions between hemisphere effects and response conditions (e.g., Laeng & Peters, 1995). Thus, it is unlikely that the hand of response could be responsible for the present findings.

Some of the more interesting results were negative, and hence must be interpreted with caution. Notably, the hemispheres performed comparably for "yes" or "no" trials (i.e., correct and incorrect picture-name matches). This finding may not be surprising because every incorrect subordinate match was from the same basic-level class, and we predicted that the RH would be superior at distinguishing them whereas the LH would tend to ignore the differences. Moreover, for basic-level matches, if the LH is better at forming category representations (e.g., prototypes), then it should be able easily to reject any shape that does not match the prototype representation activated by the label. Thus, our predic-

tions about hemispheric specialization for "no" trials would be the same as those for "yes" trials.

We must also note that the famous faces' stimuli yielded the same visual field differences we found with the animals and artifacts stimuli. This is remarkable because faces are clearly different from other visual stimuli (cf. Laeng & Caviness, 2001) and there are suggestions that faces may be processed by a separate, RH-based, system (Kanwisher, McDermott, & Chun, 1997; McCarthy, Puce, Gore, & Allison, 1997). However, Gauthier and colleagues (1997) have found, using fMRI, that the same areas in the RH that are activated by faces are also activated when people verify exemplar names for objects (e.g., verifying the name "pelican" when seeing one), which suggests an alternative explanation. Namely, known faces (i.e., familiar people) are often referred to with proper names, which are exemplar names. In light of Gauthier and colleagues' (1997) results, the RH advantage observed in our experiment with proper names of faces would reflect the subordinate level of identification, not the particular stimulus used (i.e., faces). Moreover, when we used the male/female judgment as our hypothetical entry-level label, we found indeed a LH advantage. The finding supports our intuition that a face's sex can be used as a basic or entry level for faces. It seems that the majority of faces we experience in a lifetime (i.e., faces of unfamiliar individuals) can be categorized only at levels based on perceptual features that index sex, age, or ethnicity. Indeed, several researchers have recently underlined how "the sex of the face is perhaps its most salient feature" (O'Toole, Vetter, Troje, & Bülthoff, 1997, p. 75). For this reason, sex seems a good candidate for being a "natural category" (cf. Rosch, 1973). In addition, there is evidence that (a) information about a person's sex might be extracted perceptually rather "early" (in terms of visual computation and cortical distance from V1; e.g., Andreasen et al., 1996; Courtney, Ungerleider, Keil, & Haxby, 1996); (b) that the perceptual information about sex is preserved across different spatial scales (Schyns & Oliva, 1999); and (c) that information about sex is processed independently from face identity (Bruce & Young, 1986; Bruce, Ellis, Gibling, & Young, 1987; Roberts & Bruce, 1988). We surmise that in order to access information about personal identity, one first must access the perceptual exemplars corresponding to each individual, and that the full set of these face exemplars may be stored in the RH (including specific views of each of the stored faces, see Laeng & Rouw, 2001). Thus, it seems likely that humans possess distinct prototype representations for female and male human faces.

To conclude, our findings are consistent with the view that when an object is identified as a specific instance (exemplar), it is processed differently than when it is identified as a member of a basic-level class. We propose

that the LH includes a mechanism that identifies objects as members of basic-level classes better than do the mechanisms in the RH, whereas the RH includes a mechanism that identifies objects as exemplars better than do the mechanisms in the LH. These separate subsystems produce different visual representations by selecting or discarding and transforming different properties of information in the perceptual input.

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