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Hemispheric lateralization of semantic feature distinctiveness

M. Reilly^a, N. Machado^a, and S. E. Blumstein^{a,b}

^aDepartment of Cognitive, Linguistic and Psychological Sciences, 190 Thayer Street, Brown University, Providence, RI, 02912

^bBrown Institute for Brain Science, Brown University, Providence, RI

Abstract

Recent models of semantic memory propose that the semantic representation of concepts is based, in part, on a network of features. In this view, a feature that is distinctive for an object (a zebra has stripes) is processed differently from a feature that is shared across many objects (a zebra has four legs). The goal of this paper is to determine whether there are hemispheric differences in such processing. In a feature verification task, participants responded ‘yes’ or ‘no’ following concepts which were presented to a single visual field (left or right) paired with a shared or distinctive feature. Both hemispheres showed faster reaction times to shared features than to distinctive features, although right hemisphere responses were significantly slower overall and particularly in the processing of distinctive features. These findings support models of semantic processing in which the dominant left hemisphere more efficiently performs highly discriminating ‘fine’ encoding, in contrast to the right hemisphere which performs less discriminating ‘coarse’ encoding.

Keywords

semantic memory; lateralization; categorization; visual half-field

1 Introduction

1.1 Shared and distinctive features

How do you know the characteristics of a zebra? If asked to list the features of a zebra, you might mention that it has black and white stripes, or that it has four legs. Having black and white stripes is a *distinctive* feature because it distinguishes zebras from other mammals such as horses or cheetahs. Having four legs, on the other hand, is a *shared* feature across the mammal category because it identifies similarities between the zebra and its semantic neighbors. Potential processing differences between shared and distinctive features have been examined in the neuropsychological literature, and particularly in patients with semantic dementia (SD). SD is a frontotemporal dementia characterized by temporal lobe damage. These patients show a gradual decline in semantic knowledge, often with a selective deficit in accessing distinctive features ([11, 14, 19, 24, 26]. For example, a patient

might identify every picture of an animal as “dog”, ignoring a zebra's stripes, a cheetah's spots, etc. Some patients also show intrusions of false features which are shared across other members of a category; for example, when asked to draw a duck, a SD patient drew an animal with four legs and a tail [4].

1.2 Feature Type in healthy adults

There is less evidence regarding how Feature Type (shared/distinctive status) is processed in healthy adults, and the literature has produced conflicting results with some studies showing a processing advantage for shared features and others showing a processing advantage for distinctive features. Randall et al. [29] examined processing of distinctive versus shared features for categories of living things (e.g. animals and fruits) and for nonliving things (e.g. tools and vehicles). Using a feature verification task, during which participants responded “yes” or “no” to features paired with basic-level concepts (zebra / has stripes), they showed faster verification latencies to shared features than to distinctive features, but only within trials which included living things. Raposo et al. [30] also found overall faster verification times for shared features relative to distinctive features. Using a lexical decision paradigm, Grondin, Lupker and McRae [12] showed faster reaction-time latencies for words as a function of the number of shared features belonging to a concept: the more shared features, the faster the reaction time (interestingly, no differences emerged as a function of the number of distinctive features that represented a word). Taken together, these findings suggest that shared features are facilitated during semantic retrieval.

In contrast, Cree et al. [7] reported the opposite effect. Using a feature verification task, they showed faster responses to distinctive features than to shared features across semantic categories. Based on their results, they concluded that distinctive features have a “privileged status” in semantic processing.

The results above suggest that at least for the category of living things, there is a difference in the processing of distinctive and shared features. It remains unclear why there is a processing advantage for shared features in some cases and an advantage for distinctive features in others.

1.3 Are there hemispheric differences in processing shared and distinctive features?

While there appears to be a difference in the processing of shared and distinctive features, little is known about the neural substrates underlying this processing. Although SD patients almost always have left hemisphere disease, they often have bilateral lesions [14, 32]. Thus, it is unclear whether their deficit in accessing distinctive features reflects a left-hemisphere or a bilateral impairment. Indeed, there is a more general debate in the literature on semantic processing as to whether the integration of semantic features is restricted to the left hemisphere [3, 25] or whether both hemispheres contribute to the integration of semantic features [20, 28].

One popular model of the lateralization of semantic memory proposes that the two hemispheres differ in how they encode semantic relatedness [2, 16]. In this model, the left hemisphere preferentially encodes strong (e.g., knife/cut) semantic relationships in contrast to weaker relationships (glass/cut); the literature refers to this preference as a “finely

encoded” semantic network. The right hemisphere, on the other hand, has less discriminatory ability between strongly and weakly associated semantic representations, and is moderately sensitive to all semantic relationships (termed a “coarsely encoded” network).

It is possible that the fine/coarse encoding model can be extended to the processing of distinctive and shared features if distinctive features require finely tuned access to a specific concept possessing that feature and shared features require coarse access to a group of related concepts. One functional magnetic resonance imaging (fMRI) investigation provides indirect evidence supporting this view. Tyler et al. [37] contrasted a domain-level naming task (“living” in response to a picture of a zebra) with basic-level naming (“zebra” in response to the same picture of a zebra) during fMRI. Since naming a particular animal requires access to the properties that make it distinct from other animals, it could be assumed that accessing the basic-level name of a picture (“zebra”) requires access to its distinctive features. In contrast, domain-level naming does not require access to distinctive features, since for example the “living” semantic domain is defined by the characteristics a zebra shares with other animals. Tyler et al. found the left entorhinal cortex to be more activated during basic-level naming than domain-level naming and the right middle frontal gyrus to be more activated during domain-level naming. They suggest that the left hemisphere's preference for basic-level naming reflects fine encoding, and the right hemisphere's preference for domain-level naming reflects coarse encoding.

The goal of the current experiment is to examine in more detail the processing of distinctive and shared features, in particular across the two hemispheres, and test the predictions of an extended fine/coarse encoding model using a more direct manipulation than that used by Tyler et al. We propose that the left hemisphere will show a sensitivity to the processing of shared versus distinctive features. In contrast, we predict that coarse coding in the right hemisphere could be manifested in one of two ways: the right hemisphere may fail to show such a difference in the processing of shared and distinctive features, or, alternatively, may show particular difficulties in processing distinctive features.

2 Methods

2.1 Participants

Thirty right-handed native English speakers with no history of neurological or hearing disorders participated and provided informed consent in compliance with the Brown University Institutional Review Board. Participants were compensated for their time.

2.2 Stimuli

Two hundred concept-feature pairs were selected from the feature norms developed by McRae et al. [22]. McRae et al. collected feature norms in a 541-concept database and characterized each feature as “distinctive” if it was named for two or fewer concepts, and “shared” otherwise. From these concept-feature pairs, we selected 100 living things and 100 nonliving man-made artifacts. Each concept was paired with one distinctive feature and one shared feature. Thus, there were four conditions: living – shared (e.g., peach – is sweet), living – distinctive (peach – feels fuzzy), nonliving – shared (e.g., boots – worn in winter),

and nonliving – distinctive (e.g., boots – worn by cowboys). Two hundred additional pairs were also prepared as fillers. Half included a living concept paired with a conceptually unrelated feature (e.g., “almond” / “is a type of berry”) and half had a nonliving concept paired with a conceptually unrelated feature (e.g., “musket” / “found in orchestras”). Four lists were created such that each concept appeared with each feature type crossed with visual field (Left/Distinctive, Left/Shared, Right/Distinctive, and Right/Shared) on one list. See Appendix A for a list of stimuli.

Table 1 lists parameter values for each condition. Living and nonliving concepts did not differ significantly in Frequency according to the SUBTLEX-US database [5], nor did they differ according to the Kucera-Francis measures reported by McRae et al. [17, 22].

Consistent with previous studies, nonliving concepts were marginally more familiar than living concepts (measured using norming values from 1–7; $F[1] = 3.8$, $p = 0.051$).

Additionally, we controlled for several parameters such that stimuli did not differ between Category (living/nonliving) or Feature Type (shared/distinctive), nor was there an interaction between Category and Feature Type. These parameters included:

- Latent semantic analysis (LSA) was computed using the University of Colorado at Boulder pairwise comparison app, which calculates a similarity score between -1 and 1 for any pair of texts (<http://lsa.colorado.edu>) [21]. LSA was measured by comparing the words in the visually presented phrase (e.g., “worn in winter”) with the Concept (“boots”). Results showed no difference between conditions: $F[1] = 1.4$ for Category main effect, other F 's < 1 .
- The length of the word in letters ($F[1] = 1.7$ for Feature Type, other F 's < 1).
- Production Frequency, measured as the number of participants in the McRae et al. [22] feature norming study who named a feature given a concept ($F[1] = 1.6$ for Feature Type, other F 's < 1). Controlling for Production Frequency is of particular importance because there has been debate in the literature about whether Production Frequency influenced the pattern of results in Randall et al. [29]. Cree et al. [7] controlled for Production Frequency and claimed that because Randall et al. did not use this explicit control in their design, their divergent results could be due to a failure of Randall et al. to control for this parameter.
- Distinctiveness (named Feature Type here), which was designed to differ between shared and distinctive conditions ($F[1] = 1206$, $p < 0.0001$). McRae et al. measured Distinctiveness as the reciprocal of the number of concepts for which a given feature was named; e.g., “tastes sweet” was named for 24 different concepts and has a distinctiveness value of $1/24$; “feels fuzzy” was named only for “peach” and has a distinctiveness value of 1 . There was no difference as a function of Category, nor was there an interaction between Category and Feature Type (F 's < 1).

2.3 Procedure

Stimuli were presented and responses were recorded using E-Prime 2 software [31]. Stimulus presentation took place on a Dell desktop computer and responses were entered using a keyboard.

Subjects were asked to place their chins in a chin rest located 56 cm from the computer monitor. Figure 1 shows a schematic of a single trial. Following a 1000 ms central fixation ('+ ') during each trial, a visual stimulus appeared to the left and right of fixation. The target word was presented in one visual field such that no part of the word was less than 2.3 degrees visual angle from the center of the screen. A row of six X's was presented in the other visual field. In the center of the stimulus was a caret (<or>) which indicated the side of the screen containing the target word. Participants were asked to fixate on the caret. Word presentation lasted 80 ms to prevent saccades to one side of the screen.

Following lateralized word presentation, a central fixation cross appeared for 300 ms followed by the central presentation of a semantic feature for 2000 ms in the form of a question (e.g., "has stripes?"). Participants were asked to press 1 on the keyboard number pad with the index finger of their dominant (right) hand if the feature was appropriate for the target word (test trials), and 2 with the second finger of their dominant hand if it was not (filler trials). If participants did not respond within 2000 ms, the trial terminated. A 1000 ms ITI followed.

Trials were split into four blocks of 100 trials each; 50 trials in each block were test trials and 50 were fillers, presented in a different randomized order to each participant. No participant saw the same concept more than once. The entire experiment lasted approximately 40 minutes.

3 Results

3.1 Analysis of Results

Both performance and reaction-time measures were taken. Responses were submitted to a within-subject $2 \times 2 \times 2$ (Visual Field $\times$ Category $\times$ Feature Type) Analysis of Variance (ANOVA) using R. Five participants were eliminated from the analysis: four for failure to reach an a priori threshold of 67% accuracy rate on attempted trials, and one for failure to respond to at least 50% of trials. The five excluded participants were also the only five participants with a d' -prime score of less than 2, suggesting that the excluded participants had poor accuracy across both critical and filler trials, and that the success of the remaining participants was not driven by a bias towards 'yes' responses.

The mean rate of response in the remaining 25 participants was 86.4% and the mean accuracy rate on these trials was 82.8%. Results were analyzed for accuracy on trials with a response as well as reaction times on correct trials. Trials were removed from the RT analysis if responses were more than three standard deviations above the mean reaction time for each individual participant in each condition.

3.2 Accuracy

Figure 2 shows the results across Hemisphere, Category and Feature Type. A $2 \times 2 \times 2$ Hemisphere (here and from now on, "right hemisphere" refers to left visual field responses; "left hemisphere" refers to right visual field responses) $\times$ Category (living/nonliving) $\times$ Feature Type (shared/distinctive) ANOVA is reported in Appendix B. The ANOVA revealed a main effect of Hemisphere ($F[1] = 17.192$, $p < 0.0001$), and simple effects

showed that a left-hemisphere advantage emerged within every condition except the distinctive features of living things (living - shared: $t[24] = 2.104$, $p = 0.046$; living - distinctive: $t[24] = 0.935$, $p > 0.1$; nonliving - shared: $t[24] = 4.098$, $p < 0.0004$; nonliving - distinctive: $t[24] = 3.823$, $p = 0.0008$). A main effect of Category also emerged ($F[1] = 35.861$, $p < 0.0001$) and simple effects show a significant difference between living and nonliving concepts in both hemispheres (left: $t[24] = 4.053$, $p = 0.0004$, right: $t[24] = 4.147$, $p < 0.0003$). Finally, we found an interaction between Hemisphere and Category ($F[1] = 14.023$, $p = 0.0001$) that appears to be driven by poorer accuracy for nonliving stimuli in the right hemisphere (Figure 3). No other effects emerged.

A logistic regression was also performed on the data to take into account both Subject and Item influences on performance [15]. Subject and Item (word) were included as random intercepts, and Hemisphere, Category, and Feature Type were included as fixed effects and were centered prior to analysis. The analysis used the lme4 package in R [1] and corresponding p-values were estimated using the package lmerTest [18]. The pattern of results was similar to the ANOVA: main effects of Hemisphere ($\beta = 0.0357$, $SE = 0.0053$, $t = 6.791$, $p < 0.0001$) and Category ($\beta = 0.0464$, $SE = 0.0081$, $t = 5.731$, $p < 0.0001$) emerged in addition to an interaction between Hemisphere and Category ($\beta = 0.0209$, $SE = 0.0053$, $t = 3.978$, $p < 0.0001$). A marginal interaction between Hemisphere and Feature Type also emerged ($\beta = 0.0093$, $SE = 0.0052$, $t = 1.770$, $p = 0.077$).

3.3 Reaction times

Figure 4 and Figure 5 show the results for reaction time (RT). A $2 \times 2 \times 2$ ANOVA showed a main effect of Hemisphere ($F[1] = 26.517$, $p < 0.0001$) which reflected a left-hemisphere advantage, such that a left-hemisphere advantage emerged in all four conditions (living - shared: $t[24] = 2.604$, $p = 0.016$; living - distinctive: $t[24] = 4.286$, $p = 0.0003$; nonliving - shared: $t[24] = 2.724$, $p = 0.012$; nonliving - distinctive: $t[24] = 5.395$, $p < 0.0001$). A main effect of Category emerged ($F[1] = 17.562$, $p = 0.0003$) such that living things were significantly faster than nonliving things in both the right ($t[24] = 3.336$, $p = 0.003$) and left ($t[24] = 3.780$, $p = 0.001$) hemispheres. We found a main effect of Feature Type ($F[1] = 37.924$, $p < 0.0001$) due to an advantage for shared features, such that that shared features were significantly faster than distinctive features for both the right ($t[24] = 6.281$, $p < 0.0001$) and left ($t[24] = 2.136$, $p = 0.043$) hemispheres. The Feature Type effect also emerged within both living ($t[24] = 3.986$, $p = 0.0005$) and nonliving ($t[24] = 3.539$, $p = 0.002$) concepts. Finally, an interaction emerged between Hemisphere and Feature Type ($F[1] = 5.094$, $p = 0.033$), due to slowed responses to distinctive features in the right hemisphere (see Figure 5).

4 Discussion

4.1 Shared vs. distinctive features

Our results contribute to the conflicting findings examining behavioral effects in the processing of distinctive and shared features. The current pattern of effects is consistent with those studies showing a processing advantage for shared versus distinctive features [29, 30]. The current experiment explicitly controlled for Production Frequency and still showed a

processing advantage for shared features. Thus, it is not the case that, as suggested by Cree et al. [7], the results of Randall et al. [29] were driven by a failure to control for Production Frequency. However, in contrast to our study, Randall et al. failed to show a difference between distinctive and shared features for nonliving things. Several differences between studies could account for this: the stimulus lists were different sizes (80 in Randall et al., 200 here) and consisted of different categories (nonliving concepts in Randall et al. were restricted to tools and vehicles while the current study used a wider range of categories). In addition, the distinctive features of nonliving things in Randall et al. had particularly high association strength relative to the other conditions (nonliving-shared, living-distinctive, living-shared), which might have artificially facilitated RTs to these stimuli.

It is also possible [34] that the timing of stimulus presentation drives some differences in effects between studies. The current results resemble those studies showing a processing advantage for shared features [29, 30] but show the reverse of Cree et al. [7]. Cree et al. used a long temporal window for stimulus presentation (300 ms), while Randall et al. used a presentation window of 60 ms which was similar to the timing parameters used in the current study (80 ms). Taylor et al. [34] suggested that the shared-feature advantage is greatest early in semantic processing, and distinctive features have a processing advantage during later temporal windows. Indeed, magnetoencephalography (MEG) activity is higher during an early temporal window (first 120 ms) for shared features than for distinctive features; likewise, activity was higher for distinctive features than for shared features during later temporal windows (post-200 ms; [6]). This suggests that general, category-shared semantic information is activated before concept-specific information.

4.2 Lateralization of shared/distinctive feature processing

Both hemispheres showed an RT advantage for processing shared features relative to distinctive features. Nonetheless, the right hemisphere was at a processing disadvantage for both shared and distinctive features compared to the left hemisphere, and while it distinguished shared vs. distinctive features, it was particularly slow to access distinctive features. Taken together, these results suggest that the left hemisphere plays a dominant role in processing semantic features. They also dovetail well with the fine/coarse encoding model proposed by Beeman [16]. The patient literature suggests that the left hemisphere is critical for processing distinctive features but that both hemispheres are capable of processing shared features. The current results suggest that even in healthy adults, the right hemisphere is slow to process semantic features and it is particularly slow at processing distinctive features. This is consistent with the view that the right hemisphere employs coarse encoding in that it is particularly slow to access concept-specific information, although it can access category-general information. Note that even for shared features, the right hemisphere is robustly slower than the left. Thus, the current data replicate the well-established left-hemisphere dominance effect for processing language even in the processing of the semantic features of words.

The current results also shed light on a model of lateralization which draws a distinction between categorical and associative semantic relationships [8, 13]. This model proposes that categories emerge from clusters of shared features, while associative relationships (e.g., dog-

leash, which do not necessarily share semantic features) require access to more high-level contextual information about concepts. It has been suggested that although both hemispheres have access to semantic features, only the left hemisphere accesses contextual, associative information [10]. Such a model might predict that the right hemisphere has a strong preference for shared features, which define categories, while the left hemisphere has a wider range of semantic processing strengths.

The results are also interesting in light of the view that features which are shared across the same concepts form dense networks of frequently co-occurring, or “correlated”, features [9, 33, 35, 36]. For example, the features 'has two eyes' and 'can see' tend to co-occur within the same concepts. As a result, they form a strong connection and mutually activate each other. 'Has stripes' does not consistently co-occur with any other features and is therefore more difficult to access. Indeed, it has been shown that highly correlated features are processed more quickly during a feature verification task [23]. Although the current results do not directly test for the influence of correlatedness on left and right hemisphere processing, a right-hemisphere preference for highly correlated features could explain our finding that the right hemisphere is selectively slow to process distinctive features, which are not highly correlated.

4.3 Category-specific effects

Living things elicited better performance than nonliving artifacts for both hemispheres in both accuracy and reaction time. Past research investigating semantic features and categories has shown the features of living things are more highly correlated overall than the features of nonliving things [35, 38]. Given that performance is higher for more correlated features [23], it is unsurprising that the current results show an advantage for living things. In fact, this result replicates the results of Pilgrim, Moss and Tyler [27], who interpret the disadvantage for nonliving things as reflecting the low correlatedness of their features.

We also found an interaction in accuracy such that the error rate for nonliving things was particularly high in the right hemisphere. This effect also emerged in Pilgrim, Moss and Tyler [27], who interpreted the interaction in terms of fine and coarse encoding. They proposed that coarse coding in the right hemisphere could reflect an inability to process features which are not highly correlated, such as those in nonliving concepts.

5 Conclusion

The results of the current study support models of semantic processing in which concepts are organized into a network-like architecture containing feature attributes. Features which are shared across concepts are easier to access owing to a richer set of network connections compared to those that are distinctive since they have fewer network connections. This architecture is common to both right and left hemispheres. Nonetheless, the right hemisphere appears to have greater difficulty accessing the semantic properties of words, as shown by slower reaction-time latencies. Additionally, consistent with the coarse/fine encoding model [16], the right hemisphere has greater difficulty in accessing distinctive features resulting in a processing advantage for shared features.

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Appendix A. List of Stimuli

Target	Shared feature	Distinctive feature
alligator	lives in swamps	lives in Florida
ant	has six legs	lives in a colony
apple	is crunchy	used for cider
banana	grows on trees	eaten by monkeys
beans	can be cooked	have protein
bear	can be brown-colored	has paws
beaver	lives in water	lives in a dam
beets	grows in the ground	stains
birch	can be tall	has peeling bark
blueberry	can be eaten raw	eaten in jams
buffalo	is endangered	lives in the prairie
bull	has horns	lives in Spain
butterfly	is colorful	grows from caterpillar
cabbage	eaten in soups	eaten in coleslaw
calf	has hooves	eaten as veal
camel	can be ridden	has a hump
carrot	is nutritious	good for eyesight
cat	can be a pet	is a feline
caterpillar	lives in trees	has many legs
celery	has leaves on it	is stringy
cherry	has a pit	can be maraschino
chicken	has a beak	can be fried
clam	is a type of seafood	can contain pearls
cockroach	can be dirty	is exterminated
coconut	is hard	contains milk
cod	has gills	lives in the Atlantic
corn	is a vegetable	has husks
cow	eats grass	eaten as beef
coyote	has a tail	lives in packs
crab	has claws	walks sideways
crow	is a type of bird	squawks
deer	has antlers	has a white tail

Target	Shared feature	Distinctive feature
dog	is domestic	chases cats
dolphin	lives in oceans	can be trained
dove	has feathers	symbol of peace
duck	lays eggs	has a bill
eagle	has wings	symbol of freedom
elephant	is large	has a trunk
falcon	is a type of predator	has talons
flea	bites	lives on pets

Target	Shared feature	Distinctive feature
fox	hunted by people	is sly
frog	moves by hopping	croaks
garlic	has a strong smell	repels vampires
goat	lives in mountains	eats anything
goose	migrates	lives in Canada
grape	made into juice	used for raisins
grapefruit	can be peeled	eaten at breakfast
hawk	eats rodents	sees well
horse	moves fast	used for racing
lamb	can be soft	has wool
lemon	has oval shape	used for drinks
lime	is citrus	used in Sprite
lion	lives in jungles	is ferocious
moth	can be grey	eats clothing
mushroom	is poisonous	has a cap
oak	grows in forests	home for animals
olive	eaten on pizza	used in martinis
onions	has skin	have layers
orange	contains juice	has pulp
owl	eats mice	hoots
ox	can be furry	ploughs
panther	lives in the wild	is sleek
peach	tastes sweet	feels fuzzy
peacock	lives in zoos	long tail feathers
pear	has a stem	grows in summer
peas	are nutritious	grow in pods
pepper	can be black	used to flavor
pickle	is round in shape	tastes salty
pig	can be pink	has a curly tail
pigeon	can fly	lives in cities

Target	Shared feature	Distinctive feature
pine	used to make furniture	has needles
pineapple	is tropical	feels prickly
pony	has hair	has a long mane
potato	can be baked	can be mashed
pumpkin	grows on vines	can be carved
rabbit	has whiskers	eats carrots
radish	eaten in salads	tastes hot/spicy
rat	has teeth	carries disease
rattlesnake	slithers	is slender
robin	builds nests	has a red breast
rooster	has feet	seen in morning

Target	Shared feature	Distinctive feature
salamander	is a type of reptile	is a type of lizard
sardine	can be slimy	comes in a can
seaweed	a type of plant	grows in the sea
sheep	eaten as meat	lives in herds
snail	has antennae	lives in a shell
spider	eats flies	spins webs
spinach	is healthy	eaten by Popeye
strawberry	has seeds	grows in fields
swan	has webbed feet	is graceful
tiger	found in circuses	roars
toad	can be ugly	can have warts
tomato	grows in gardens	eaten as sauce
tortoise	can swim	lives a long time
turkey	lives on farms	eaten with gravy
turtle	has a head	snaps at people
vulture	lives in deserts	eats dead flesh
wasp	lives in a nest	stings
willow	has branches	has droopy branches
worm	crawls	eaten by birds
airplane	used for travel	has a propeller
ambulance	has four wheels	has a siren
anchor	made of iron	sinks
apron	made of cloth	worn in kitchens
armour	is silver	worn by knights
ashtray	made of glass	used for cigarettes
axe	has a blade	used by lumberjacks
bagpipe	used for music	is Scottish
balloon	made of rubber	can burst

Target	Shared feature	Distinctive feature
banner	is rectangular	used to advertise
barn	found in the country	stores farm equipment
barrel	is a container	stores water
basement	can be cold	is damp
basket	used to hold things	made of wicker
bathtub	holds water	used to wash
baton	is long	used by twirling
beehive	is yellow	found in trees
belt	has holes	has buckles
bench	has four legs	at bus stops
bike	has a seat	has a bell
biscuit	is food	eaten with tea
blender	is electrical	makes drinks

Target	Shared feature	Distinctive feature
blouse	worn on torso	has a collar
bolts	made of metal	used with screws
boots	worn in winter	worn by cowboys
bouquet	is pretty	found in vases
bread	eaten with butter	made with yeast
brick	can be red	used in houses
broom	made of wood	removes dust
cabin	used on vacation	made of logs
cage	has a lock	made of wire
candle	is decorative	burns
cannon	is heavy	used on ships
canoe	can float	can tip
cape	worn for warmth	worn on shoulders
catapult	used in war	used to throw
cathedral	associated with religion	has benches
chandelier	can be shiny	made of crystal
cheese	eaten in sandwiches	can be melted
cigar	produces smoke	made of tobacco
clamp	used for carpentry	used in surgery
crowbar	is a type of weapon	used by thieves
crown	made of gold	has jewels
doll	used by children	associated with babies
drain	found in kitchens	found in bathtubs
drapes	can be opened	keep out light
drum	used in bands	produces a beat
elevator	has buttons	goes up and down

Target	Shared feature	Distinctive feature
emerald	is expensive	is a birth stone
envelope	made of paper	seals
football	made of leather	has stitching
garage	has doors	used to store tools
gate	can be closed	has a latch
gloves	made of wool	keeps hands warm
gown	worn by women	is elegant
grenade	explodes	has a pin
guitar	has strings	uses a pick
hammer	used for construction	used to pound
harp	used for classical music	associated with angels
hatchet	is sharp	used to chop
helicopter	has a pilot	can hover
helmet	worn on the head	worn while on a bicycle
hoe	used to dig	has a metal blade

Target	Shared feature	Distinctive feature
hut	type of house	made of straw
jar	is breakable	holds jam
kettle	can get hot	produces steam
kite	is a type of toy	requires wind
ladle	is a utensil	is a type of spoon
limousine	uses gasoline	contains a TV
medal	made of bronze	related to winning
mirror	found on walls	can break
mittens	come in pairs	have thumbs
necklace	type of jewelry	has a clasp
nylons	worn on legs	are sheer
oven	is hot	has racks
pan	has a lid	made of cast iron
parka	worn in rain	has a lining
pearl	feels smooth	is valuable
piano	a musical instrument	contains ivory
pliers	found in toolboxes	used to grip
racquet	used for sports	used for squash
raft	used on water	made of logs
raisin	is a type of fruit	is wrinkled
robe	found in bathrooms	worn with pajamas
rocket	travels fast	used in space
saddle	has straps	has stirrups
sandals	have soles	worn at beaches

Target	Shared feature	Distinctive feature
shield	is medieval	used with swords
shovel	used in garden	moves snow
sink	has pipes	can clog
skis	worn on feet	needs poles
spear	used for fishing	is primitive
submarine	used to transport	has a periscope
subway	has passengers	is underground
surfboard	is flat	used on waves
taxi	is a type of car	costs money
thimble	is small	worn on fingers
trumpet	made of brass	has valves
violin	used in orchestras	has a chin rest
yacht	has an engine	used by rich people

Appendix B. Full results of ANOVA and mixed-effects regressions

Accuracy: ANOVA		
Contrast	<i>F</i> (all df=1)	<i>p</i>
Hemisphere	17.192	<0.0001
Category	35.861	<0.0001
Feature Type	1.455	>0.1
Hemisphere × Category	14.023	0.0010
Hemisphere × Feature Type	2.587	>0.1
Category × Feature Type	2.467	>0.1
Hemisphere × Category × Feature Type	<1	>0.1

Accuracy: linear mixed-effects				
Contrast	$\beta\beta$	Standard error	<i>t</i>	<i>p</i>
Hemisphere	0.0357	0.0053	6.791	< 0.0001
Category	0.0464	0.0081	5.731	< 0.0001
Feature Type	0.0073	0.0053	1.388	> 0.1
Hemisphere × Category	0.0209	0.0053	3.978	< 0.0001
Hemisphere × Feature Type	0.0093	0.0052	1.770	0.077
Category × Feature Type	0.0054	0.0053	1.019	> 0.1
Hemisphere × Category × Feature Type	> 0.0001	0.0052	0.007	> 0.1

Reaction times: ANOVA		
Contrast	<i>F</i> (all df=1, 24)	<i>p</i>
Hemisphere	26.517	<0.0001
Category	17.562	<0.0001

Reaction times: ANOVA		
Contrast	<i>F</i> (all df=1, 24)	<i>p</i>
Feature Type	37.925	<0.0001
Hemisphere × Category	1.424	>0.1
Hemisphere × Feature Type	5.094	0.033
Category × Feature Type	<1	>0.1
Hemisphere × Category × Feature Type	<1	>0.1

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Figure 1.
Experimental design.

Figure 2.

Accuracy results for Hemisphere, Category and Feature Type. Error bars indicate standard error.

Figure 3.
Accuracy results for Hemisphere and Category. Error bars indicate standard error.

Figure 4. Reaction time results for Hemisphere, Category and Feature Type. Error bars indicate standard error.

Figure 5. Reaction time results for Hemisphere and Feature Type. Error bars indicate standard error.

Table 1

Summary of Stimuli. Mean (SD).

Variable	Living	Nonliving
Frequency (SUBTLEX-US)	12.73 (23.3)	9.66 (8.8)
Familiarity	5.33 (1.69)	5.67 (1.78)

	Living		Nonliving	
Variable (range)	Shared	Distinctive	Shared	Distinctive
Semantic similarity: LSA (−1 – 1)	0.138 (0.14)	0.149 (0.16)	0.121 (0.15)	0.131 (0.13)
Feature length (5–24)	12.54 (3.47)	13.31 (3.55)	13.14 (3.56)	13.30 (3.54)
Production Frequency (5–30)	10.89 (5.56)	9.85 (5.65)	10.73 (4.90)	10.39 (5.51)
Distinctiveness (0–1)	0.149 (0.11)	0.840 (0.23)	0.174 (0.13)	0.838 (0.24)