

1-1-2004

Hemispheric specialization in the coding of spatial relations

Glenn Eric Casner
Iowa State University

Follow this and additional works at: <https://lib.dr.iastate.edu/rtd>

Recommended Citation

Casner, Glenn Eric, "Hemispheric specialization in the coding of spatial relations" (2004). *Retrospective Theses and Dissertations*. 20370.

<https://lib.dr.iastate.edu/rtd/20370>

This Thesis is brought to you for free and open access by the Iowa State University Capstones, Theses and Dissertations at Iowa State University Digital Repository. It has been accepted for inclusion in Retrospective Theses and Dissertations by an authorized administrator of Iowa State University Digital Repository. For more information, please contact digirep@iastate.edu.

Hemispheric specialization in the coding of spatial relations

by

Glenn Eric Casner

A thesis submitted to the graduate faculty
in partial fulfillment of the requirements for the degree of
MASTER OF SCIENCE

Major: Psychology

Program of Study Committee:
Eric E. Cooper (Major Professor)
Veronica J. Dark
William Robinson

Iowa State University

Ames, Iowa

2004

Graduate College
Iowa State University

This is to certify that the master's thesis of
Glenn Eric Casner
has met the thesis requirements of Iowa State University

Signatures have been redacted for privacy

TABLE OF CONTENTS

INTRODUCTION	1
Representation of Relations in Modern Theories of Object Recognition	2
The Coordinate-Relations Hypothesis	3
Current Alternatives to the Coordinate-Relations Hypothesis	6
The Biological Recognition Hypothesis	7
The Subordinate Level Recognition Hypothesis	8
The Expert Recognition Hypothesis	8
Purpose of the Present Experiments	9
EXPERIMENT ONE	12
Method	14
Participants	14
Apparatus	14
Procedure	15
Results	17
Response Time Data	18
Error Data	19
Discussion	20
EXPERIMENT TWO	22
Method	24
Participants	24
Apparatus	24
Procedure	24
Results	25
Response Time Data	26
Error Data	27

Discussion	28
GENERAL DISCUSSION	30
REFERENCES	33

INTRODUCTION

Among vision researchers there is a growing consensus that there are two neurologically distinct visual recognition systems: one recognition system that subserves face recognition (and perhaps recognition of other classes of stimuli as well) and another recognition system that subserves most forms of basic-level object recognition and that these two visual recognition systems differ in terms of how they represent shape (Farah, 1995). There are multiple lines of evidence suggesting that the brain regions that underlie face recognition are distinct from the brain regions that underlie basic-level object recognition.

One of the strongest lines of evidence suggesting a distinction between face recognition and basic-level object recognition are disorders that show a double dissociation between the two processes. That is, there are brain-damaged patients, known as prosopagnosics, who are impaired at recognizing faces but show intact non-face object recognition, whereas there are brain damaged patients, known as object-agnosics, who are impaired at recognizing objects but show intact face recognition (see Farah, 1992, for a review). A second line of evidence is that numerous neuroimaging studies have found brain regions that respond selectively to faces (e.g., Kanwisher, McDermott, & Chun, 1997; McCarthy, Puce, Gore, & Allison, 1997; Sergent, Ohta, & MacDonald, 1992). A third line is that many visual half-field studies have found that face recognition is faster and more accurate when the faces are presented in the left visual field and thus initially to the right cerebral hemisphere than when the faces are presented in the right visual field and thus initially to the left cerebral hemisphere (see Davidoff, 1982, and Ellis, 1983, for reviews). In contrast, visual half-field studies typically find no hemispheric effect or a slight left hemisphere advantage for basic-level object recognition (Biederman & Cooper, 1991; Levine

& Banich, 1982; Young, Bion, & Ellis, 1980). In addition to providing evidence that there is a distinction between face recognition and basic-level object recognition, studies with brain-damaged patients, neuroimaging studies, and visual half-fields studies provide evidence that the recognition system that subserves face recognition is localized primarily in the right cerebral hemisphere (or operates more efficiently in the right cerebral hemisphere). In contrast, studies typically find that the recognition system that subserves basic-level object recognition is bilateral (Brooks & Cooper, 2001). While most prosopagnosics have bilateral lesions, lesions restricted to the right cerebral hemisphere can produce prosopagnosia (Damasio, Tranel, & Damasio, 1990; De Renzi, Perani, Carlesimo, & Silveri, 1994). Neuroimaging studies typically show preferential activation of the right fusiform gyrus (also known as fusiform face area) in response to faces (e.g., Kanwisher et al., 1997; McCarthy et al., 1997).

Although most vision researchers now agree that there is not one visual recognition system but actually two distinct systems, there is currently a heated debate as to what sorts of recognition tasks these different systems subserve. The evidence now suggests that the face recognition system is not used solely to recognize faces, but is also used to recognize other classes of stimuli (e.g., Damasio, Damasio, & Van Hoesen, 1982; Diamond & Carey, 1986). However, the questions of exactly what sort of tasks are mediated by the two recognition systems, and how the representation of shape differs in the two systems remain open.

Representation of Relations in Modern Theories of Object Recognition

Modern theories of object recognition for the most part can be divided into two groups on the basis of what the primitives of an object are and how the relations among the

primitives are coded: structural description theories or template theories. Structural description theories (e.g., Biederman, 1987; Hummel & Biederman, 1992) posit that objects are represented as a collection of simple volumetric primitives (i.e., geons) that correspond roughly to the parts of the object, and the locations of these visual primitives are specified using primitive-to-primitive, categorical relation such as “above”, “below”, and “side-of”. In contrast to structural description theories, template theories (e.g., Bulthoff, 1992; Edelman & Weinshall, 1991; Ullman, 1989) typically do not break an object down into its parts, but rather rely on simpler primitives such as edges or pixels, and in template theories the precise location of the primitives are coded via primitive-to-reference point coordinate relations.

The Coordinate-Relations Hypothesis

According to the coordinate relations hypothesis, the distinction between the two visual recognition systems is in how they represent object shape (Brooks & Cooper, 2001; Cooper & Wojan, 2000). The coordinate relations hypothesis theorizes that the recognition system that mediates most basic-level object recognition represents shape using a structural description representation whereas the recognition system that mediates face recognition represents shape via a coordinate relations representation.

According to the coordinate relations hypothesis, the factor determining which visual recognition system mediates a given recognition task is the computational demands of the task. That is, because the basic-level object recognition system is more efficient than the face recognition system, if the recognition task can be preformed using a structural description representation then the task will be performed by the basic-level object recognition system. According to the co-ordinate relations hypothesis, if the visual

recognition task cannot be performed using a structural description representation, then the task will be performed by the face recognition system using a coordinate relations representation. That is, if the task requires precise metric information, then the task will be performed by the face recognition system and show a right hemisphere advantage.

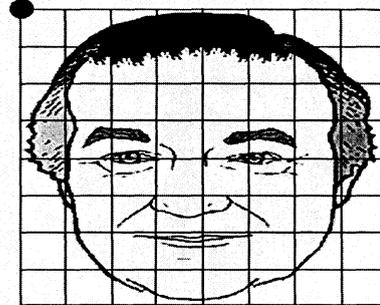
In a coordinate relations representation the precise distance of each primitive from a fixed reference point or set of fixed reference points is represented. A coordinate relations systems representation would be equivalent to laying graph paper over an object and specifying the locations of the primitives in the representation relative to the origin of the graph. An example of how a categorical relations system and a coordinate relations system might represent the spatial locations of the visual primitives is illustrated in Figure 1. A categorical relations system might represent the spatial location of the left eye in the following manner: The left eye is to the side of the right eye, above and to the side of the nose, and above and to the side of the mouth. A coordinate relations system might represent the spatial location of the left eye in the following manner: The eye is 4 units below and 2.5 units to the right of the reference point.

Categorical Relations



Left eye is side-of right eye, above and side-of nose, and above and side of mouth.

Coordinate Relations



Left eye is 4 units below and 2.5 units to the right of the reference point.

Figure 1. Illustration of how the spatial position of the primitive corresponding to the eye might be coded using categorical relations (in the left face) and coordinate relations (in the right face).

Notice that because of the way that the categorical relations system represents the shape of objects, it is extremely good at putting objects into groups if they have the same structural description, but the categorical relations system is incapable of distinguishing between two objects with the same structural description. The coordinate relations hypothesis posits that only when the categorical relations system is incapable of completing the recognition task, such as distinguishing between two objects with the same structural description, does the coordinate relations system mediate the recognition task. The categorical relations system is theorized to mediate a task if possible due to the fact that a system that represents objects using a categorical structural descriptions has computational advantages over a coordinate relations system. For example, a categorical relations system would allow for invariance with respect to rotation in depth, and invariance with respect to size, but the categorical relations system does have its drawbacks as well. As Brooks and

Cooper (2001) pointed out that the categorical relations system would be unable to distinguish between faces or between a dog (such as a collie) and a fox. Notice that using a categorical relations system, the representations of various faces would be identical (see Figure 2 for an illustration) and thus a coordinate representation would be required to distinguish different faces.

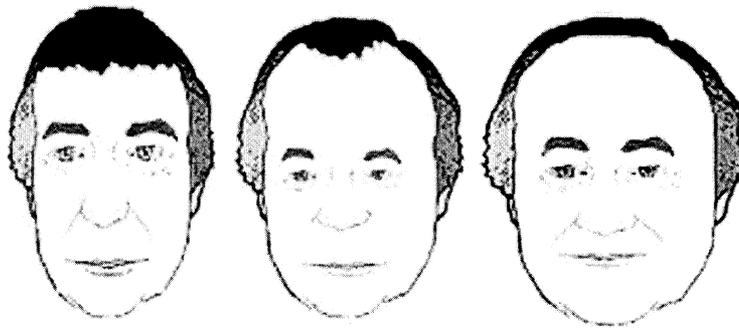


Figure 2. A recognition system using categorical spatial relations among the visual primitives would activate the same representation for all three of the above faces, despite wide variation in the size, position, and aspect ratios of the primitives between the different faces.

Thus, the coordinate relations hypothesis makes precise predictions concerning which recognition tasks should be mediated by the coordinate relations system.

Current Alternatives to the Coordinate-Relations Hypothesis

Currently, three main alternatives to the coordinate relations hypothesis dominate the literature in this area. In the following section, each of these hypotheses will be discussed, some of the evidence for each will be listed, and it will be noted how the coordinate relations hypothesis can account for the data explained by each of the alternatives.

The Biological Recognition Hypothesis. One of the main hypotheses that attempts to account for the dissociation in neural subsystems for visual recognition posits that the face recognition system mediates the recognition of all biological stimuli and the basic-level object system mediates the recognition of non-biological stimuli (Cappa et al., 1998; Caramazza & Shelton, 1998; Chao, Haxby, & Martin, 1999, Chao, Martin, & Haxby, 1999; Perani et al., 1999). Many neuroimaging studies, including positron emission topography (PET) studies and functional magnetic resonance imaging (fMRI) studies, have found brain regions in the lateral fusiform gyrus that respond selectively to biological stimuli (e.g., animals and faces) whereas brain regions in the medial fusiform gyrus that respond selectively to non-biological stimuli (e.g., tools and houses) (Chao, Haxby, et al., 1999; Chao, Martin, et al., 1999). The most common co-occurring symptom of prosopagnosia is an inability to distinguish among four-legged animals. Although the fact that damage localized to the right hemisphere can lead to an inability to recognize faces and animals is not conclusive evidence for the biological recognition hypothesis, it does provide strong evidence that the recognition of faces and animals (both biological stimuli) have neural hardware in common.

Note that the coordinate relations hypothesis can account for why biological stimuli might tend to show a right hemisphere advantage whereas non-biological stimuli do not. As mentioned before, many biological stimuli share structural descriptions whereas non-biological stimuli tend not to share the same structural descriptions. According to the coordinate relations hypothesis, distinguishing between two things that have the same structural descriptions requires the use of the coordinate relations system and therefore should show a right hemisphere advantage. Thus, according to the coordinate relations

hypothesis, it is not the biological/non-biological distinction that determines what visual recognition system mediates a task; it is the computational demand of the recognition task.

The Subordinate Level Recognition Hypothesis. Another theory that attempts to account for the dissociation in neural subsystems for visual recognition posits that the face recognition system mediates subordinate level recognition, whereas the basic-level recognition system mediates basic-level recognition (Damasio et al., 1982; Gauthier et al., 1997; Gauthier, Skudlarski, Gore, & Anderson, 2000). Subordinate level tasks are tasks that require distinguishing between members of the same basic-level category (e.g., distinguishing between a 1967 Mustang and a 1968 Mustang). One line of evidence for the subordinate level hypothesis is that some neuroimaging studies have shown that subordinate level recognition tasks produce higher levels of activation in the fusiform face area (Gauthier, 1997). Also, recent visual half-field studies have found a right hemisphere advantage for subordinate level object recognition (Marsolek, 1999; Marsolek, Kosslyn, & Squire, 1992).

Note that the coordinate relations hypothesis can account for the data supporting the subordinate level recognition hypothesis. Members of the same basic-level category often share the same general structural description and thus would require the use of the coordinate relations system to distinguish between them. In contrast, distinguishing between objects at the basic-level typically involves different structural descriptions and thus could be accomplished using the categorical relations system.

The Expert Recognition Hypothesis. The third main theory that attempts to account for the dissociation in neural subsystems for visual recognition posits that the neural subsystem that mediates face recognition mediates any recognition task at which the individual is an expert (Diamond & Carey, 1986; Gauthier, 2000; Gauthier & Tarr, 1997;

Tarr & Gauthier, 2000). One of the lines of evidence in support of the expert recognition hypothesis is that experts show an inversion effect for recognizing classes of objects in which they are experts that is very similar to the inversion effect found for recognizing faces (Diamond & Carey, 1986). An inversion effect is when stimuli that have been inverted are drastically more difficult to recognize than when they are right-side up. For example, dog and car experts show similar inversion effects for recognizing objects within their class of perceptual expertise similar to the inversion effect normal individuals show with faces. Another line of evidence in support for the expert recognition hypothesis is that fMRI studies show that perceptual expertise recruits regions similar to those used in face recognition (Gauthier, 2000; Gauthier, 1999). However, as Kanwisher (2000) pointed out, the expert recognition hypothesis fails to explain why certain classes of expert perceptual recognition tasks (e.g., recognition of alphanumeric stimuli) fail to show a right hemisphere advantage.

Notice that the coordinate relations hypothesis can also account for these data as well. The recognition tasks that have been used to test the expert recognition process require the use of the coordinate relations system, but recognition of alphanumeric stimuli can be accomplished via the categorical relations system. For example, distinguishing between most breeds of dogs or between most makes of cars would require the use of the coordinate relations system while distinguishing between an “a” and a “b” would not.

Purpose of the Present Experiments

One of the main problems with the experiments that have attempted to test the biological recognition hypothesis, coordinate relations hypothesis, expert recognition hypothesis, and subordinate-level recognition hypothesis are that the stimuli used cannot be

arbitrarily assigned to be in one class or another. For example, stimuli are either of a biological nature or of a non-biological nature. The main problem with the biological recognition hypothesis, expert recognition hypothesis, and subordinate-level recognition hypothesis is that they fail to specify what about stimuli being biological or not, or what about stimuli being of a class in which the individual is an expert, or what about classifying stimuli at the subordinate-level causes them to be recognized by a different system. These theories fail to specify how the representations of shape in the two recognition systems differ. For example, what is it about the representations of stimuli for which the individual is an expert that differs from the representations of stimuli for which the individual is not an expert?

The present set of experiments tested the coordinate relations hypothesis while holding constant other variables that have been theorized to underlie the dissociation in neural visual recognition systems (e.g., biological or non-biological distinction, level of expertise, level of categorization). The present set of experiments utilized abstract nonsense line drawings that were constructed so as to produce two distinct classes of changes: categorical changes and coordinate changes. Both of these changed stimulus types were constructed from a common set of baseline abstract nonsense line drawings. Although the categorical change and coordinate change were constructed by altering the baseline shapes precisely the same amount metrically, the stimuli were constructed so as to ensure that the structural description of the categorical change class differed from that of the baseline shapes but the structural description of the coordinate change class maintained the same structural description as that of the baseline shapes. With stimuli of this nature, the coordinate relations hypothesis predicts that distinguishing a particular baseline shape from its categorical change

version would be mediated by the categorical recognition system and distinguishing a particular baseline shape from its coordinate change version would require the use of the coordinate recognition system. A right hemisphere advantage has been hypothesized to be a marker for when one recognition task is mediated by the right hemisphere recognition system (Cooper & Wojan, 2000; Brooks & Cooper, 2001). Thus, a right hemisphere advantage is hypothesized for the coordinate change class, but no hemispheric advantage is hypothesized for the categorical change class.

EXPERIMENT ONE

The purpose of Experiment 1 was to test the coordinate-relations hypothesis using nonsense line drawings. To be more precise Experiment 1 tested whether or not “above” and “below” are part of the categorical structural description representations used by the bilateral recognition system. If “above” and “below” are part of the categorical structural description representations used by the bilateral recognition system then the coordinate-relations hypothesis would predict a RH advantage for the coordinate change but non hemispheric advantage for the categorical change. (See Figure 3 for an illustration of the stimuli used in Experiment 1.)

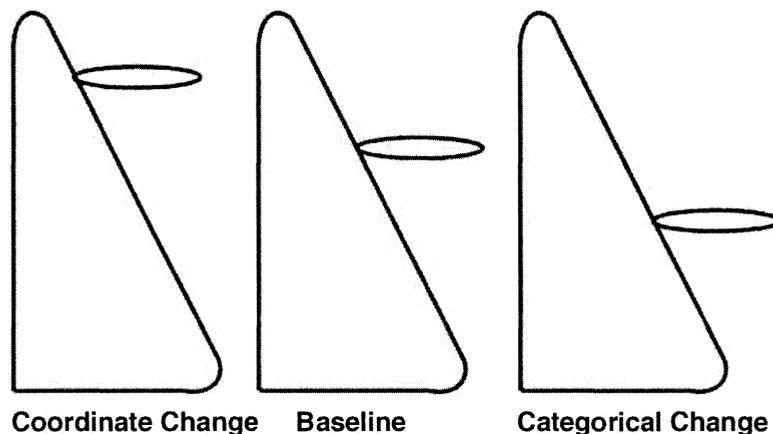


Figure 3. Illustration showing an example of a baseline shape and its corresponding categorical change version and coordinate change version. Notice that while both the categorical and coordinate change versions were constructed by moving the eclipse equal distances from its location in the baseline, the structural description of the baseline shape (i.e., an ellipse “above” and “to the side-of” a triangle) stayed intact in the coordinate change version but was altered in the categorical change version (the ellipse is “below” the midpoint of the triangle for the categorical change).

To construct the categorical change versions, the position of the smaller of the two shapes in the baseline stimuli was changed in such a way that the categorical description of the relationship between the two shapes is modified. For example, the structural description of the baseline shape in Figure 3 might be an ellipse “above” and “to the side of” a triangle. The movement of the smaller shape down $\frac{3}{4}$ of an inch would change the structural description of the categorical change shape in Figure 3 to an ellipse “below” and “to the side of” a triangle. To construct the coordinate change versions, the position of the smaller of the two shapes in the baseline stimuli was changed in an equal and opposite direction to the movement that produced the categorical change (i.e., $\frac{3}{4}$ of an inch up). The only difference, other than direction, was that this change of position did not change the structural description from that of the baseline shape (i.e., the structural description of the coordinate change shape in Figure 3 would be an ellipse above and to the side of a triangle). This manipulation would keep the structural description the same for the coordinate change versions and the baseline versions while keeping the metric change from baseline equal for the categorical change versions and the coordinate change versions.

Thus, the coordinate-relations hypothesis predicts that distinguishing the coordinate changed stimuli from baseline should show a RH advantage due to these two versions sharing the same structural descriptions whereas distinguishing the categorical changed stimuli from baseline should not show a hemispheric advantage due to these two versions differing in structural descriptions. As stated previously, the coordinate-relations hypothesis posits that only when the categorical relations system is incapable of completing the recognition task (i.e., distinguishing between two objects with the same structural description) does the coordinate relations system mediate the recognition task.

Method

Participants

The participants were 4 right-handed male¹ volunteers who reported normal or corrected to normal vision. Hand preference was determined by having participants complete the Edinburgh Handedness Inventory (Oldfield, 1973) in which participants indicated on a five point scale (i.e. Always Right, Sometimes Right, Either Hand, Sometimes Left, and Always Left) the hand used when performing a variety of motor tasks including writing, drawing, and throwing.

Apparatus

The experiment was controlled by a Power Macintosh G3 all-in-one computer using SuperLab Pro software. Subjects responded using a Cedrus RB-600 response box that, in conjunction with SuperLab Pro, gives ± 0.5 ms response time accuracy. Stimuli were presented on an Apple 15-inch color monitor with a resolution of 832 X 624 pixels and a vertical refresh rate of 75Hz.

Stimuli for the experiment consisted of black and white line drawings of 432 abstract shapes constructed using Adobe Illustrator 10.0 software. The stimuli were constructed so as to produce 36 baseline nonsense objects each comprised of two shapes. Each of the 36 baseline nonsense objects was manipulated in such a way as to produce a categorical change version and a coordinate change version. See Figure 3 for examples of stimuli.

¹ Laterality studies typically utilize only right-handed males, because the brains of right-handed males tend to be the most lateralized. The brains of females and left-handed males are sometimes more functionally symmetrical or may even show the reverse pattern of lateralization. By utilizing only right-handed males it is easier to find hemispheric asymmetries. For an extensive discussion concerning the relationship between sex, handedness, and hemispheric lateralization, see Springer and Deutsch (1998).

Stimuli were sized so as to ensure that their maximum extent fits into a 300 x 300 pixel box. Examples of stimuli may be seen in Figure 3. A mirror-image version of each object was created to ensure that the distance from foveal vision of the features used for discrimination was balanced for visual field presentation across the experiment.

Furthermore, for each of the 108 original line drawings and each of their corresponding mirror-image versions, an inverted version was created by rotating each image 180° in the picture plane.

Procedure

Presentation of the stimuli was self-paced. Participants pressed one of the buttons on the button box to begin each trial. After pressing one of the buttons on the button box, a fixation cue was presented on the computer screen for 507 msec, followed by presentation of the first stimulus (one of the baseline shapes) in central fixation for 200 msec, followed by a pattern mask for 756 msec. The pattern mask was a collection of random lines and served to eliminate any possible after-image from the first stimulus. The pattern mask was followed by presentation of the second stimulus (either an identical image, the coordinate version of that object, or the categorical version of that baseline shape) for 148 msec. The 148 msec presentation duration was chosen to ensure that the presentation duration was too brief for the participant to make a second eye fixation. The second stimulus was lateralized such that the closest edge of the image was 2.4° of visual angle to the left or to the right of central fixation. Lateralization of the second stimulus was presented to one of four possible lateralized positions (up and to the right, down and to the right, down and to the left, or up and to the left) to prevent participants from just using the height of the secondary shape as an indicator of whether or not the two stimuli are identical.

The participant's task was to decide whether the second image presented was identical to the first image presented. The participant was instructed to push the "same" button if the two images are identical and to push "different" button if the two images are not identical. After each trial, the participants received feedback concerning the accuracy of their response.

The experiment consisted of 4608 trials (divided into four blocks of 1152 trials each). Each of the 144 baseline line-drawings (36 baseline shapes x 2 (upright or inverted) x 2 (original or mirror-image)) served as the first image for 32 trials: 16 trials in which the second stimulus was identical to the first, four trials in which the second stimulus was the categorical version of the corresponding baseline shape (one in each of the four possible lateralization positions), and four trials in which the second stimulus was the coordinate version of the corresponding baseline shape (one in each of the four possible lateralization positions). The order in which the stimuli were presented was chosen randomly with half of the participants seeing the stimuli in forward order and half in reverse. Also, each of the participants completed two blocks in which the left button was the "same" button and two blocks in which the right button was the "same" button. For half of the participants, the "same" button was on the left for the first block of trials, and for half it was on the right.

Participants completed 16 practice trials prior to each block of trials using the same presentation conditions used during the actual experiment. The practice stimuli were constructed in the same manner as the experimental stimuli. None of the practice stimuli were presented in the experiment proper.

Results

The mean response times for the “same” trials were 440 msec (RVF/LH) and 435 msec (LVF/RH), and the mean error-rates for the “same” trials were 9.2% (RVF/LH) and 10.1% (LVF/RH). Only the data from the “different” trials were analyzed because only they were relevant to the hypothesis (i.e., the trials in which the second stimulus was either the coordinate version shape or the categorical version shape). The mean response times from Experiment 1 are shown in Figure 4. Response times and error rates were subjected to a within subjects analysis of variance (ANOVA) with Hemisphere of Presentation (Right vs. Left) and Change Type (Categorical Change vs. Coordinate Change) as the factors in the analysis.

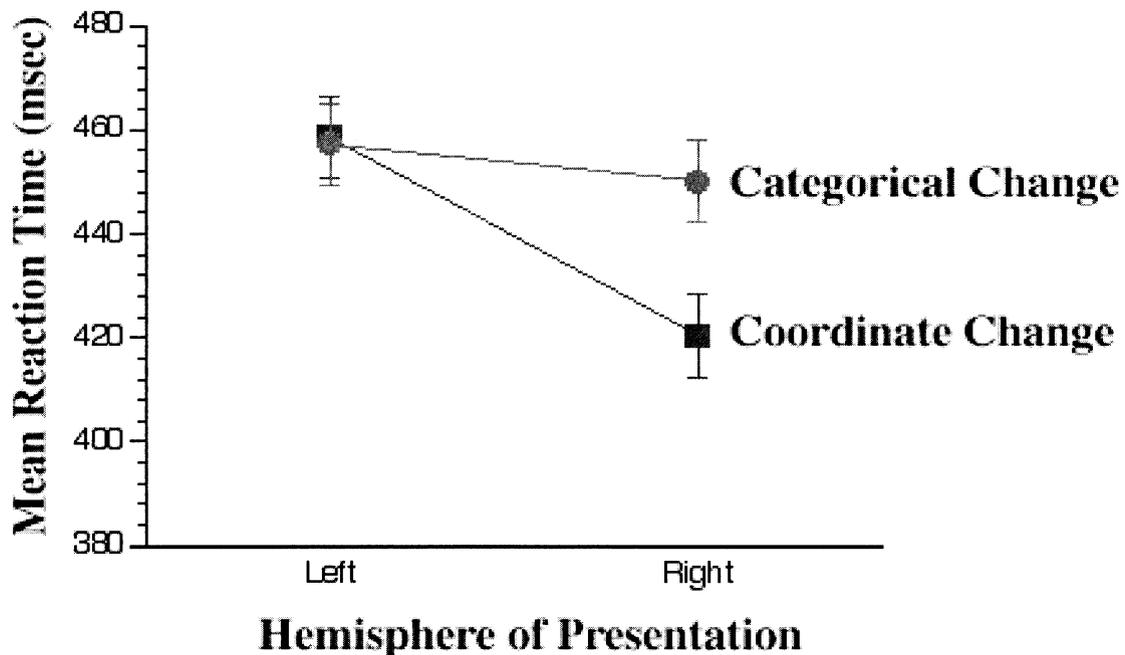


Figure 4. Response time data from Experiment 1. Error bars represent standard error of the mean (Loftus & Loftus, 1988).

Response Time Data. There was a reliable main effect of type of change $F(1,35)=11.80, p<.01, MSE = 615.36$. Overall, participants were faster at distinguishing the coordinate change (mean RT = 439) than they were at distinguishing the categorical change (mean RT = 454). The analysis also revealed a reliable main effect of hemisphere of presentation $F(1,35)=62.11, p<.0001, MSE = 300.76$. Overall, participants were faster at distinguishing the stimuli when presented in the LVF/RH (mean RT = 435) than they were at distinguishing the stimuli when presented in the RVF/LH (mean RT = 458). There was also a reliable interaction between type of change and hemisphere, $F(1,35)=19.18, p<.001, MSE = 452.44$. Planned contrasts revealed a reliable LVF/RH advantage for distinguishing the coordinate change $F(1,35)=58.38, p<.0001$ whereas no hemispheric effects were found for distinguishing the categorical change $F(1,35)=2.09, p>.15$. The reliable main effect of type of change and the reliable main effect of hemisphere of presentation can be explained primarily by the reliable interaction between type of change and hemisphere.

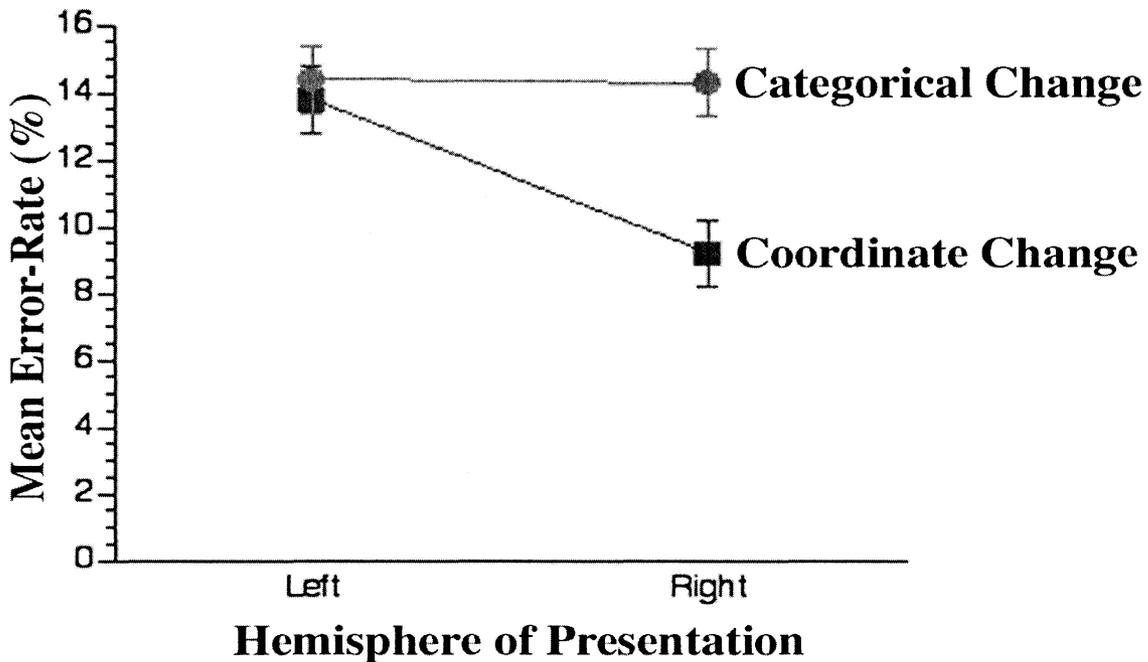


Figure 5. Error-rate data from Experiment 1. Error Bars represent standard error of the mean.

Error Data. The error data from Experiment 1 are shown in Figure 5. Error data showed a reliable main effect of type of change $F(1,35)=5.30$, $p<.05$, $MSE = 0.005$. Overall, participants were better at distinguishing the Coordinate Changes (mean error-rate [ER] = 12.5%) than they were at distinguishing the Categorical Changes (mean ER = 14.3%). The analysis also revealed a reliable main effect of hemisphere of presentation $F(1,35)=13.52$, $p<.001$, $MSE = 0.001$. Overall, participants were better at distinguishing the stimuli when presented in the LVF/RH (mean ER = 11.7%) than they were at distinguishing the stimuli when presented in the RVF/LH (mean ER = 14.1%). There was a reliable interaction of type of change and hemisphere, $F(1,35)=7.15$, $p<.05$, $MSE = 0.003$. Planned contrasts revealed a reliable LVF/RH advantage for distinguishing the coordinate change $F(1,35)=14.568$, $p<.001$

whereas no hemispheric effects were found for distinguishing the categorical change $F(1,35)=0.001, p>.95$.

Discussion

The results from Experiment 1 demonstrate that there is a right hemisphere advantage for recognizing the metric change where as there is no hemispheric advantage for recognizing the categorical change, just as the coordinate-relations hypothesis would predict. That is, a right hemisphere advantage was found when participants were required to physically compare stimuli sharing the same categorical relations between their parts but no hemispheric specialization was found when comparing stimuli with different relations between their parts. These results suggest that there is a right hemisphere visual recognition system that is used to identify stimuli that share the same categorical relations among their parts.

As previously stated, Cooper and Wojan, (2000) theorized that the bilateral recognition system that mediates most forms of basic-level object recognition is used to perform any recognition task that can be accomplished using a structural description representation, and the right hemisphere subsystem that subserves face recognition is used to perform any recognition task that requires precise metric information. It should be noted that participants were actually faster at distinguishing the coordinate change type of stimuli than they were at distinguishing the categorical change type of stimuli. These findings suggest that perhaps the coordinate recognition system not only performs recognition tasks that the categorical system cannot perform but that perhaps for some tasks the coordinate recognition system may actually be more efficient than the categorical recognition system.

The purpose of Experiment 1 was to test the coordinate-relations hypothesis while controlling for other variables that have been theorized to underlie the dissociation in neural visual recognition systems (e.g., biological or non-biological distinction, level of expertise, or level of processing). Notice that neither the biological recognition hypothesis, nor the expert recognition hypothesis, nor the subordinate-level recognition hypothesis would predict any difference with respect to hemisphere between the coordinate change and the categorical change. The biological recognition hypothesis posits that the right hemisphere system mediates biological stimuli and the bilateral system mediates non-biological stimuli, and thus would predict no hemispheric effect for either the coordinate change or the categorical change due to neither one being biological in nature. Similarly, the expert recognition hypothesis would predict no hemispheric effect for either the coordinate change or the categorical change due to fact that participants were not experts for either type of stimuli. Also, the subordinate-level recognition hypothesis would predict no hemispheric effect for either the coordinate change or the categorical change due to neither task being a subordinate-level recognition task. Only the coordinate-relations hypothesis predicts a right hemisphere advantage for the coordinate change type of stimuli and no laterality effect for the categorical change type of stimuli.

EXPERIMENT TWO

The results of Experiment 1 also indicate that “above-below” categorical relationships are a component of the structural descriptions used by the bilateral recognition system. Although Biederman (1987) theorized that the structural relations would involve “above”, “below”, and “side-of” relations, such speculation was based solely on computational demands. This raises the question as to whether or not the categorical structural descriptions encode just “side-of” relations, or whether they specify “right-of” vs. “left-of” relations. A recognition system that specifies the location of the primitive using just “above”, “below”, and “side-of” relations would be immediately invariant with respect to rotation in depth, whereas a recognition system that specified “right-of” vs. “left-of” relations would only be invariant to rotation in depth up to a point (about 180 degrees of rotation). The purpose of Experiment 2 was to address whether or not the structural descriptions encoded just “side-of” relations, or whether they specify “right-of” vs. “left-of” relations using the nonsense line drawing stimuli from Experiment 1. The stimuli for Experiment 2 were identical to that of Experiment 1 except that there was an additional type of stimuli created by rotating each stimulus 90° degrees in the picture plane (see Figure 6 for illustration).

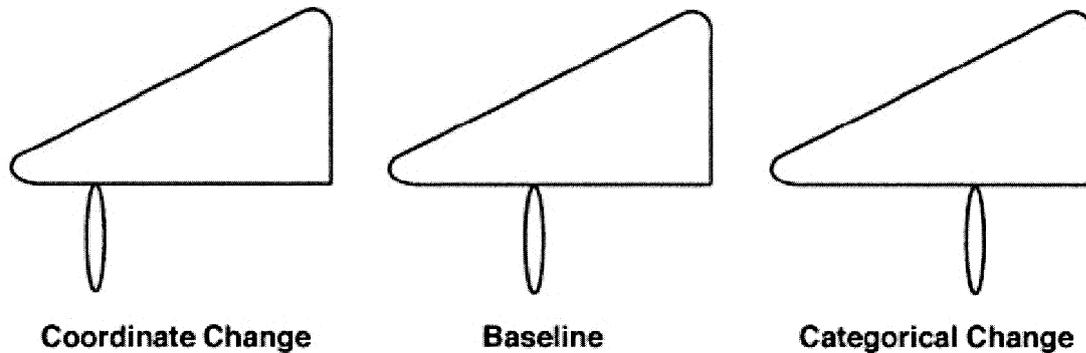


Figure 6. Illustration showing an example of a baseline shape and its corresponding categorical change version and coordinate change version where the major axis is the horizontal axis. Notice that if the structural descriptions only specify “side-of” relationships and not “left” or “right” relationships, then both the categorical and coordinate change manipulations kept the structural description of the baseline shape (i.e., an ellipse “below” and “to the side-of” a triangle) intact. However, if the structural descriptions specify “right-of” and “left-of” relations, then the manipulation only leaves the baseline structural description of the baseline shape (i.e., an ellipse below and to the left of a triangle) intact only for the coordinate change version.

If the structural descriptions specify only “side-of” relations and not “left-of” vs. “right-of” relationships, then among the horizontal stimuli both the coordinate change and the categorical change would not represent a change in structural description from that of the corresponding baseline shapes, thus one would predict a RH advantage for both categorical and coordinate change type of stimuli. However, if the structural descriptions specify “left-of” vs. “right-of” relationships, then for both the horizontal axis stimuli and for the vertical axis stimuli, only the categorical change would represent a change in the structural description from that of the corresponding baseline shapes. Thus if “left-of” vs. “right-of” relations are coded in the structural descriptions, then the coordinate-relations hypothesis

would predict a RH advantage for the coordinate change but no laterality effect for the categorical change.

Method

The method for Experiment 2 was identical to the method of Experiment 1 in all but two respects. First, in addition to the 432 stimuli used in Experiment 1, an additional stimulus for each was created by rotating each of the 432 stimuli 90° in the picture plane, thereby changing the major axis of the stimulus from vertical to horizontal bringing the total number of stimuli to 864. (See Figure 4 for examples.) Second, the participants completed four blocks of 1152 trials for a total of 4608 trials so as to ensure that the experiment could be completed in the allotted time.

Participants

The participants for Experiment 2 were the same participants that completed Experiment 1.

Apparatus

The apparatus used to control presentation of the stimuli was identical to that used in Experiment 1.

Procedure.

The procedure for Experiment 2 was identical to that of Experiment 1 with the exception that the stimuli were shown half as often in order to ensure that the experiment could be completed in the allotted time.

Results

The mean response times for the “same” trials were 418 msec (Vertical RVF/LH), 408 msec (Vertical LVF/RH), 420 msec (Horizontal RVF/LH), and 435 msec (Horizontal LVF/RH). The mean error-rates for the “same” trials were 9.1% (Vertical RVF/LH), 8.7% (Vertical LVF/RH), 8.8% (Horizontal RVF/LH), and 10.2% (Horizontal LVF/RH). Once again, only the data from the “different” trials were analyzed (i.e., the trials in which the second stimulus was either a coordinate change or a categorical change from the first stimulus). The response time data from Experiment 2 are shown in Figure 7. Response times and error rates were subjected to a within subjects analysis of variance with Hemisphere of Presentation (right vs. left) and Change Type (categorical change vs. coordinate change) and Axis of Orientation (vertical vs. horizontal) as the variables in the analysis that were analyzed by stimuli.

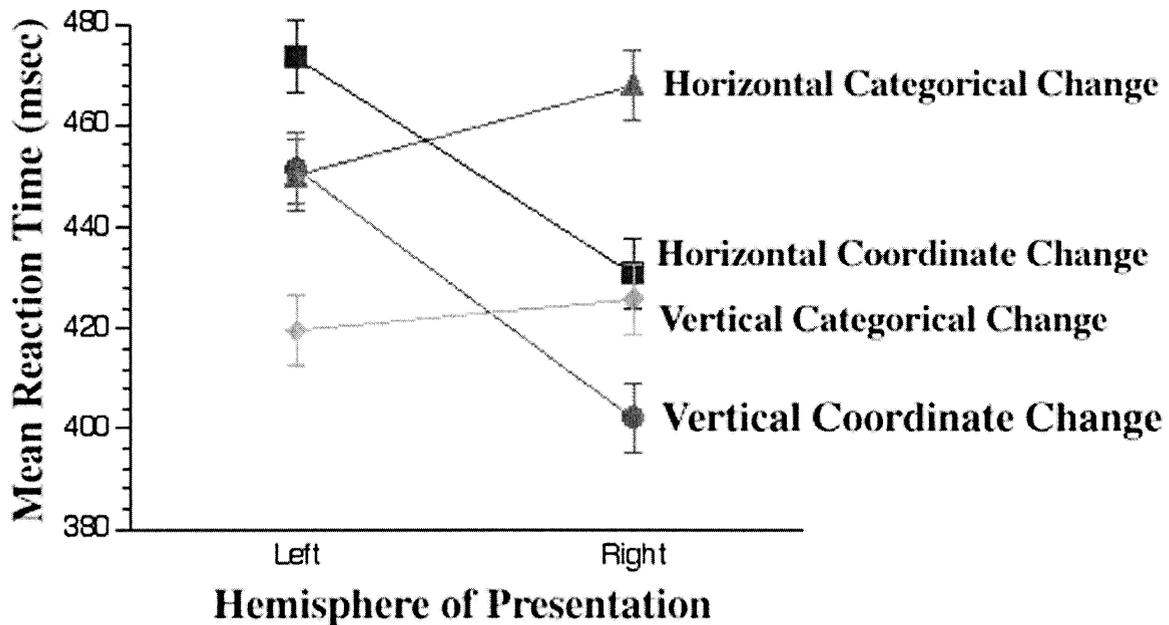


Figure 7. Response time data from Experiment 2. Error bars represent standard error of the mean.

Response Time Data. There was a reliable main effect of orientation $F(1,35)=29.94$, $p<.0001$, $MSE = 2296.305$. Overall, participants were faster at distinguishing the vertical axis stimuli (mean RT = 425) than they were at distinguishing the horizontal axis stimuli (mean RT = 456). The analysis also revealed a reliable main effect of hemisphere of presentation $F(1,35)=31.78$, $p<.0001$, $MSE = 658.24$. Overall, participants were faster at distinguishing the stimuli when presented in the LVF/RH (mean RT = 432) than they were at distinguishing the stimuli when presented in the RVF/LH (mean RT = 449). The main effect of type of change was not significant $F(1,35)=0.09$, $p>.76$, $MSE = 1434.042$. There was a reliable interaction between type of change and hemisphere, $F(1,35)=53.87$, $p<.0001$, $MSE = 1128.245$. That is, analysis revealed a LVF/RH advantage for the metric change but no

hemispheric advantage for the categorical change (see Figure 7). Both the Type of change x Orientation interaction and the Orientation x Hemisphere interaction approached significance, $F(1,35)=3.52$, $p<.069$, $MSE = 629.864$ and $F(1,35)=2.95$, $p<.095$, $MSE = 513.893$. The Type of change x Orientation x Hemisphere interaction was not significant, $F(1,35)=0.14$, $p>.70$, $MSE = 757.863$.

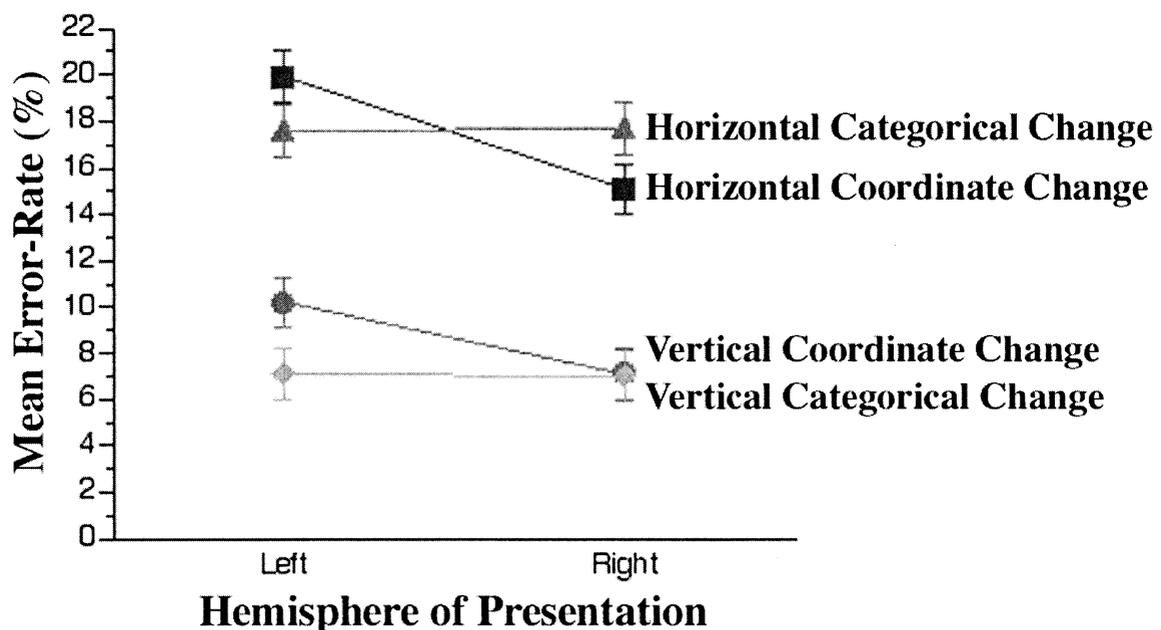


Figure 8. Error-rate data from Experiment 1. Error bars represent standard error of the mean.

Error Data. The error data from Experiment 2 are shown in Figure 8. Error data showed a reliable main effect of hemisphere of presentation $F(1,35)=7.72$, $p<.01$, $MSE = 0.004$. Overall, participants were better at distinguishing the stimuli when presented in the LVF/RH (mean ER = 11.7%) than they were at distinguishing the stimuli when presented in the RVF/LH (mean ER = 13.7%). The analysis also revealed a reliable main effect of

orientation $F(1,35)=96.80$, $p<.0001$, $MSE = 0.007$. That is, participants were better at distinguishing the vertical axis stimuli (mean ER = 7.9%) than they were at distinguishing the horizontal axis stimuli (mean ER = 17.6%). There was no reliable main effect of type of change $F(1,35)=0.31$, $p>0.05$, $MSE = 0.012$. The Type of change x Hemisphere interaction approached significance $F(1,35)=3.66$, $p>0.06$, $MSE = 0.008$. The Type of change x Orientation interaction, $F(1,35)=1.64$, $p>0.20$, $MSE = 0.003$, the Orientation x Hemisphere interaction, $F(1,35)=0.33$, $p>0.56$, $MSE = 0.003$, and the Type of change x Hemisphere x Orientation interaction were all not significant, $F(1,35)=0.22$, $p>0.63$, $MSE = 0.007$.

Discussion

The results from Experiment 2 demonstrated that once again, there is a right hemisphere advantage for recognizing the metric change whereas there is no hemispheric advantage for recognizing the categorical change regardless of orientation. This is just as the coordinate-relations hypothesis would predict. However, the analysis revealed that the Type of change x Orientation x Hemisphere interaction was not significant. This indicates that “right-of” vs. “left-of” categorical relations among parts are both coded in the categorical structural descriptions.

Recall that the coordinate-relations hypothesis predicts that if the structural descriptions specify “left-of” vs. “right-of” relationships, then for the horizontal axis stimuli and for the vertical axis stimuli only the categorical change type of stimuli would represent a change in structural description from that of the corresponding baseline shapes while the coordinate change type of stimuli would not. Thus the results of Experiment 2 suggest that

“left-of” vs. “right-of” relations are coded in the structural descriptions, because a RH advantage was found for the co-ordinate change regardless of orientation.

The analysis of response times and error-rates revealed that the horizontal axis stimuli were harder to distinguish than were the vertical axis stimuli. This is most likely an artifact of the secondary shapes being presented closer to fixation for the vertical stimuli than they were for the horizontal stimuli.

GENERAL DISCUSSION

The present set of experiments tested the coordinate relations hypothesis while keeping constant other variables that have been theorized to underlie the dissociation in neural visual recognition systems via the utilization of abstract nonsense line drawings that were constructed so as to produce two distinct classes of changes: categorical change and purely metric changes.

As the coordinate-relations hypothesis predicts, Experiment 1 found a RH advantage for the coordinate change type of stimuli and no hemispheric effect for the categorical change type of stimuli. None of the other hypotheses that attempt to explain when each of the neurologically distinct visual recognition systems would predict the findings of Experiment 1. Experiment 2 tested whether the structural descriptions used to discriminate the stimuli in the study encode just “side-of” relations, or whether they specify “right-of” vs. “left-of” relations. Experiment 2 found a RH advantage for the coordinate change but no laterality effect for the categorical change, just as would be predicted if “left-of” vs. “right-of” relations are coded in the structural descriptions. It should be noted that the task in the present studies was a discrimination task and not a recognition task in that the participants task is to discriminate whether two stimuli are physically identical contrary to most visual recognition tasks where participants task are to identify stimuli. It is possible that the representations used for visual discrimination tasks are different than the representations used for visual recognition tasks.

Cooper and Wojan, (2000) posited that the coordinate recognition system mediates visual recognition only when the categorical recognition system cannot, however it should be noted that participants were faster at distinguishing the coordinate change type of stimuli

than they were at distinguishing the categorical change type of stimuli for Experiment 1. These findings suggest that perhaps the coordinate recognition system not only performs recognition tasks that the categorical system cannot perform but that perhaps for some tasks the coordinate recognition system may actually be more efficient than the categorical recognition system. However, Experiment 2 found no difference in mean reaction time for coordinate change type and mean reaction time for categorical change type. Further research may want to explore possible causes for the different findings in the two studies.

The experiments presented here provide strong support for the coordinate-relations hypothesis that other leading theories of when the right hemisphere recognition system is used cannot account for in their current forms. The utilization of nonsense stimuli to test the coordinate-relations hypothesis allows for control of variables that have been theorized to underlie the dissociation in neural visual recognition systems, such as biological or non-biological distinction, level of expertise, and level to which the stimuli were categorized. Contrary to current structural description theories (e.g., Biederman, 1987), Experiment 2 suggests that “left-of” and “right-of” relations are explicitly coded as part of the representation used by the bilateral recognition system.

As noted earlier, one caution concerning the implications of the present experiments with regards to visual recognition theories is that the task in the present studies was a discrimination task and not a recognition task. It is possible that the representations used for visual discrimination tasks are different than the representations used for visual recognition tasks. For example, notice that for most real-world objects “left-of” and “right-of” relations are not informative with regards to assigning an object to its basic level class. That is, most real world recognition tasks would not require specifying “left-of” and “right-of” relations,

but one is capable of distinguishing between objects that are facing to the left and objects that are facing to the right. It may be that the findings reported in the present paper apply to visual discrimination tasks and not necessarily to visual recognition, however this is an area that requires further study. Regardless, the findings of Experiments 1 and 2 suggest that “above”, “below”, “left-of”, and “right-of” relations are coded for in the categorical structural descriptions mediating bilateral recognition.

REFERENCES

- Biederman, I. (1987). Recognition-by-components: a theory of human image understanding. *Psychological Review*, *94*(2), 115-147.
- Biederman, I., & Cooper, E. (1991). Object recognition and laterality: null effects. *Neuropsychologia*, *29*(7), 685-694.
- Brooks, B. E., & Cooper, E. E. (2001). *What types of recognition tasks are mediated in the right cerebral hemisphere?* Paper presented at the Meeting of the Midwestern Psychological Association, Chicago, IL.
- Bulthoff, H., & Edelman, S. (1992). Psychophysical support for a two-dimensional view interpolation theory of object recognition. *Proceedings of the National Academy of Sciences of the United States of America*, *89*, 60-64.
- Cappa, S. F., Frugoni, M., Pasquali, P., Perani, D., & Zorati, F. (1998). Category-specific naming impairment for artefacts: A new case. *Neurocase*, *4*(4-5), 391-397.
- Caramazza, A., & Shelton, J. R. (1998). Domain-specific knowledge systems in the brain: the animate-inanimate distinction. *Journal of Cognitive Neuroscience*, *10*(1), 1-34.
- Chao, L. L., Haxby, J. V., & Martin, A. (1999). Attribute-based neural substrates in temporal cortex for perceiving and knowing about objects. *Nature Neuroscience*, *2*(10), 913-919.
- Chao, L. L., Martin, A., & Haxby, J. V. (1999). Are face-responsive regions selective only for faces? *Neuroreport: For Rapid Communication of Neuroscience Research*, *10*(14), 2945-2950.
- Cooper, E. E., & Wojan, T. J. (2000). Differences in the coding of spatial relations in face identification and basic-level object recognition. *Journal of Experimental Psychology. Learning, Memory, and Cognition*, *26*(2), 470-488.

- Damasio, A. R., Damasio, H., & Van Hoesen, G. W. (1982). Prosopagnosia: anatomic basis and behavioral mechanisms. *Neurology*, 32(4), 331-341.
- Damasio, A. R., Tranel, D., & Damasio, H. (1990). Face agnosia and the neural substrates of memory. *Annual Review of Neuroscience*, 13, 89-109.
- Davidoff, J. (1982). Studies with non-verbal stimuli. In J. G. Beaumont (Ed.), *Divided visual field studies of cerebral organization* (pp. 29-55). New York: Academic Press.
- De Renzi, E., Perani, D., Carlesimo, G. A., & Silveri, M. C. (1994). Prosopagnosia can be associated with damage confined to the right hemisphere: An MRI and PET study and a review of the literature. *Neuropsychologia*, 32(8), 893-902.
- Diamond, R., & Carey, S. (1986). Why faces are and are not special: An effect of expertise. *Journal of Experimental Psychology: General*, 115(2), 107-117.
- Edelman, S., & Weinshall, D. (1991). A self-organizing multiple-view representation of 3-D objects. *Biological Cybernetics*, 64, 209-219.
- Ellis, H. D. (1983). The role of the right hemisphere in face perception. In A. W. Young (Ed.), *Functions of the Right Cerebral Hemisphere* (pp. 33-64). New York: Academic Press.
- Farah, M. J. (1992). Agnosia. *Current Opinion in Neurobiology*, 2(2), 162-164.
- Gauthier, I., Anderson, A. W., Tarr, M. J., Skudlarski, P., & Gore, J. C. (1997). Levels of categorization in visual recognition studied using functional magnetic resonance imaging. *Current Biology*, 7(9), 645-651.
- Gauthier, I., Skudlarski, P., Gore, J. C., & Anderson, A. W. (2000). Expertise for cars and birds recruits brain areas involved in face recognition. *Nature Neuroscience*, 3(2), 191-197.
- Gauthier, I., & Tarr, M. J. (1997). Becoming a "Greeble" expert: exploring mechanisms for face recognition. *Vision Research*, 37(12), 1673-1682.

- Gauthier, I., Tarr, M. J., Anderson, A. W., Skudlarski, P., & Gore, J. C. (1999). Activation of the middle fusiform 'face area' increases with expertise in recognizing novel objects. *Nature Neuroscience*, 2(6), 568-573.
- Hummel, J. E., & Biederman, I. (1992). Dynamic binding in a neural network for shape recognition. *Psychological Review*, 99(3), 480-517.
- Kanwisher, N. (2000). Domain specificity in face perception. *Nature Neuroscience*, 3(8), 759-763.
- Kanwisher, N., McDermott, J., & Chun, M. M. (1997). The fusiform face area: A module in human extrastriate cortex specialized for face perception. *Journal of Neuroscience*, 17(11), 4302-4311.
- Levine, S. C., & Banich, M. T. (1982). Lateral asymmetries in the naming of words and corresponding line drawings. *Brain and Language*, 17(1), 34-45.
- Loftus, G. R., & Loftus, E. F. (1988). *Essence of statistics* (2nd ed.).
- Marsolek, C. J. (1999). Dissociable neural subsystems underlie abstract and specific object recognition. *Psychological Science*, 10(2), 111-118.
- Marsolek, C. J., Kosslyn, S. M., & Squire, L. R. (1992). Form-specific visual priming in The right cerebral hemisphere. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 18(3), 492-508.
- McCarthy, G., Puce, A., Gore, J. C., & Allison, T. (1997). Face-specific processing in the human fusiform gyrus. *Journal of Cognitive Neuroscience*, 9(5), 605-610.
- Oldfield, R. C. (1971). The assessment and analysis of handedness: The Edinburgh inventory. *Neuropsychologia*. 1971 Mar; Vol. 9(1): 97-113.
- Perani, D., Schnur, T., Tettamanti, M., Gorno Tempini, M., Cappa, S. F., & Fazio, F. (1999). Word and picture matching: A PET study of semantic category effects. *Neuropsychologia*, 37(3), 293-306.

- Sergent, J., Ohta, S., & MacDonald, B. (1992). Functional neuroanatomy of face and object processing. A positron emission tomography study. *Brain, 115 Pt 1*, 15-36.
- Springer, S. P., & Deutsch, G. (1998). *Left Brain, Right Brain: Perspectives From Cognitive Neuroscience*. New York: Freeman.
- Tarr, M. J., & Gauthier, I. (2000). FFA: A flexible fusiform area for subordinate-level visual processing automatized by expertise. *Nature Neuroscience, 3*, 764-769.
- Ullman, S. (1989). Aligning pictorial descriptions: an approach to object recognition. *Cognition, 32*(3), 193-254.
- Young, A. W., Bion, P. J., & Ellis, A. W. (1980). Studies toward a model of laterality effects for picture and word naming. *Brain and Language, 11*(1), 54-65.